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栃木県塩原産更新世植物群による古環境解析

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Geological Survey of Japan

Eiji INOUE, Director

栃木県塩原産更新世植物群による古環境解析

Palaeoenvironmental analysis based on the Pleistocene Shiobara flora in the Shiobara volcanic basin, central Japan

尾上　亨

T. ONOE

地 質 調 査 所

平成元年3月

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March, 1989

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栃木県塩原産更新世植物群による古環境解析

尾　上　　亨*

要　旨

栃木県塩原町には塩原化石植物群を挟在する更新統の塩原層群（湖成層）が分布しており，この泥岩中に保存良好な植物化石が豊富に含まれている．

この塩原化石植物群についてはこれまでに多くの研究が行われているが，遠藤（1931—40）による“氷期形成説”が一般に認められてきた．しかし筆者は，この化石植物群に温暖な要素が比較的多く含まれていることから，氷期形成説に疑問をもち，同植物群の再検討を行った．

研究の手法としては，まず，大型化石（葉・実・花など）の分類・産出頻度の計測・記載を行った．それによって得られた植物相を現在の植物相と比較対照し，更に，花粉化石から得られたデータを加えて，化石堆積当時の気候・環境を復元した．

大型化石は11,494点の標本から51科104属171種が同定された．そのうち *Fagus crenata*（ブナ）が産出個体数において全体の約13%を占めて最も多く，塩原化石植物群はブナ林で代表される冷温帯落葉広葉樹が主体となっている．更に同植物群には，*Fagus japonica*（イヌブナ），*Castanea crenata*（クリ），*Carpinus tschonoskii*（イヌシデ），*Quercus serrata*（コナラ）など，冷温帯から暖温帯への推移帯に当たる中間温帯林の特徴種や，暖温帯植物も比較的多く含まれており，塩原化石植物群が示す古植生は，化石産地周辺の現在の植生と比較してもやや暖かい気候に対応する組成を示している．

花粉化石は *Abies, Picea, Pinus, Tsuga, Cryptomeria* などの針葉樹が8種類，*Juglans, Alnus, Betula, Fagus* 等の広葉樹が35種類，*Artemisia*，Gramineae及びシダ類を合わせた草本類が7種類で，合計50種類が識別された．花粉化石の産出傾向は，針葉樹，落葉広葉樹及び草本類の風媒花植物が優勢であるが，虫媒花植物は，大型化石が多産するのに反して極めて貧弱であった．風媒花植物は虫媒花植物に比べて一般に花粉生産量が多く，移動範囲も広いが，今回の分析結果でもその差は明確である．

塩原化石植物群堆積期には *Fagus crenata* が繁茂していたことから，全期間を通じて湿潤な気候であったことが推測されるが，その中にあって，比較的乾燥に強い *Alnus* の増減が示すように，やや乾燥した気候が時折到来していたことが花粉化石による解析から明らかとなった．

塩原層群と指交関係で介在する高原火山の安山岩がK-Ar法による全岩年代測定で約30万年前を示すことから，同化石植物群生成の年代もこれと同じであることは明らかである．本研究によって明らかになった上記の諸事実から，従来の通説であった氷期形成説を否定し，塩原化石植物群は更新世中期の間氷期に形成されたものと推定される．

* 地質標本館

Ⅰ．緒　　言

栃木県塩原地域に分布する塩原化石植物群は更新世に形成された火山山麓の小湖盆内に堆積した極めて保存のよい植物化石からなる．これらは更新世における東北日本の古植物相を代表する一つの典型例として知られ，研究成果も多い．そのなかでも，塩原化石植物群の構成要素には冷温帯に固有な種が卓越しており，これが更新世前期の氷期に形成されたものであるとする遠藤（1931～40）の見解が現在まで一般的に支持され，図鑑，辞典，教科書などには現在でもこの説が多く引用されている．

筆者は地質調査所において1954年以降本邦各地の新第三系産の植物化石について記載・分類を中心とした古生物学的研究に従事してきたが，その過程で，同所所蔵の塩原産植物化石標本中に暖温帯種に同定すべきものが相当数含まれていること，更に，遠藤の報告中には記載されていない種が多数存在することを気付くに至った．これまでの通説に疑問を投げかけるこれら資料に接し筆者はこの重要な問題を解決するために，1977年以来植物化石標本の産出地である塩原町の木の葉化石園において，野外地質調査と化石試料の採集につとめてきた．その結果，採集試料及び同園所蔵の大量の未同定化石標本中から，多数の明瞭な暖温帯種の存在を確認した．これまでの筆者の研究結果から，塩原化石植物群に関する従来の通説には大幅な修正が必要であることが明らかとなった．また，本研究の過程で塩原化石植物群には171種の大型植物化石が含まれ，それらは104属51科に及ぶが，そのうち種まで同定できた167種はいずれも現生種からなり，1種を除くほかはすべて現在関東地方北部を含む日本各地に自生するものからなることが明らかとなった．したがって，各構成要素の現在の分布域や植生などとの比較を行いながら，この豊富な化石標本を駆使することにより，量的な裏付けを持った，より的確な古環境の復元が可能であるとの見通しを持つに至った．

本論は以上の問題意識のもとに，木の葉化石園の協力を得て，筆者が1977年から1986年にわたって進めてきた塩原化石植物群の記載と，古環境復元に関する研究を総括したものである．

この研究を進めるに当たっては，まず大型化石（葉・実・花など）を正確に分類・記載し，その産出頻度を計測して得られた植物相を現在の植物相と比較対照することによって化石植物群堆積当時の気候・環境を復元するという手法をとった．また大型化石により得られた植物相に，花粉化石の推論を通して得られた知見を加えた．その結果，後節で詳しく論じるように，塩原化石植物群は現在よりもやや温暖な環境を示すものであり，氷期に生成したものであるというこれまでの通説は否定されるに至った．

謝　辞

本論文を発表するに当たり，九州大学理学部地質学教室柳田寿一教授・同学名誉教授浦田英夫博士及び同学理学部地質学教室相原安津夫教授の諸先生から内容・構成全般に関し懇切な御指導・御教示をいただいた．

北海道大学名誉教授棚井敏雅博士には機会あるごとに御鞭撻・御指導をいただいた．

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岡山理科大学蒜山研究所板谷徹丸博士には高原火山の溶岩流の年代測定をお願いした．

植物化石の同定にあたっては，宇都宮大学農学部前田禎三教授・農林水産省林業試験場谷本丈夫博士・国立科学博物館地学研究部植村和彦博士・同館筑波実験植物園橋本　保・八田洋章博士及び松本定の諸氏から懇切な御指導をいただいた．

木の葉化石園加藤信夫社長には10年間の長きにわたり化石採集の便宜を計っていただき，多くの標本を提供していただいた．

パリノ・サーヴェイ株式会社徳永重元博士には本稿の査読をお願いし有益な御助言をいただいた．

本研究を進めるに当たっては，元地質標本館長神戸信和博士・名古屋大学坂本　亨教授・地質調査所井上英二所長・地質部服部　仁部長・海洋地質部海洋底質課大嶋和雄課長・地質標本館地質標準課坂巻幸雄課長・同課一色直記及び佐藤喜男の各技官に有益な御指導・御助言をいただいた．

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II．塩原層群と塩原化石植物群に関する従来の研究

1888年，スウェーデンのA. G. NATHORSTがその論文“Zur Fossilen Flora Japan's”の中で，下野国塩谷郡塩原村（現在の栃木県那須郡塩原町）産の植物化石を記載し，塩原化石植物群を最初に公表した．この研究に用いられた塩原の植物化石は，横山又次郎がドイツに留学中の1887年に日本から取り寄せてNATHORSTに研究を依頼したもので，NATHORSTは*Fagus*等15種を識別した．NATHORST（1883）は長崎県の茂木化石植物群も記載しており，当時鮮新世前期と考えられていた同植物群［TANAI（1976）によれば鮮新世後期の可能性がある］の組成と塩原化石植物群のそれを比較検討し，塩原化石植物群は茂木化石植物群より若い鮮新世後期とするのが妥当であると述べた．金原（1900）は高原火山の地質調査に関連して現在の塩原層群から産出した植物化石27種を列記し，これに基づき塩原層群を上部第三紀層とした．

矢部（1929）は塩原火山と塩原層群の関係について述べ，その中で当時遠藤によって研究中の塩原層群産の植物化石66種を表示した．そして，この化石植物群の組成は現在の中禅寺湖畔の標高1,500 m付近の植生に近いと判断し，化石堆積当時の気候は現在の中禅寺湖畔とほぼ同じであったと推定した．また，塩原盆地に発達する段丘面と現河床との比高に基づいて，塩原化石湖形成当時の海水準を算定し，化石湖の標高は現在の塩原盆地底の標高とほぼ同じ500～600 mであったと推測した．塩原層群の地質時代については，塩原地域と関東地域の地質の共通点をもとに，これが南関東の成田層の一部と対比できると考えて更新世とした．

遠藤（1931 a）は塩原層群から産した植物化石約100種を同定し，その約90%は現生種で，絶滅種は10%にすぎないことから，その地質時代を更新世と考えた．更に遠藤は，矢部（1929）の考察をもとに，現在中禅寺湖周辺の標高1,500 m付近に生育している冷温帯上部の植物相が，塩原では化石植物群堆積当時に上記のように標高500～600 mにあったと想定するとともに，その高度差900～1,000 mに相当する気温の差を気温逓減率（高度9,000 m以下では，100 m高度を増すごとに湿潤大気の気温は平均して0.55°C逓減する）から算出して，塩原層群堆積当時の気温は現在より5～6°C低かったと結論づけた．そして，更新世前期における本州中部付近の気温が現在より5～6°C低かったという上記の推測が正しければ，当時本州にも氷河が存在したであろうと述べている．

その後，遠藤は塩原化石植物群の記載を続け，1934年にAceraceae 14種を，1940年にはAceraceaeを除く被子植物53種を記載した．

ほぼ時を同じくして，小泉（1940）は京都大学植物分類学及び植物地理学研究室所蔵の塩原層群産植物化石を検討し，50種を識別した．このうち14種は遠藤の示した化石リストにない新たに検出された種である．小泉は，自身が同定した50種に，遠藤の化石資料を補って，塩原化石植物群の解明を行った．小泉はこの化石植物群の組成から，地質時代については，更新世とする矢部（1929）や遠藤（1931 a）の考えに異議はないと述べている．しかし，塩原化石植物群の構成種は，現在の温帯南部のものと何ら異なるところがないとして，化石堆積当時の気候は現在と大差がなかったと結論した．

AKUTSU（1964）は，塩原層群の地質構造について詳しく研究し，同層群の中塩原火山角礫岩を除く須巻，宮島及び赤川の各累層から産する珪藻化石についても記載した．それによると珪藻化石は17属35種からなり，宮島層から産する珪藻の大部分は浮遊性で，それら化石から湖の深さは約30 m，当時の気候は温暖ないし寒冷であったと推測した．

鈴木三男（1973）は塩原層群の須巻・宮島・赤川の各累層から産する材化石を検討し，合計59点の

標本から7種を識別している．同氏によると，赤川層と須巻層からそれぞれ *Acer* が1個体ずつ産出しているほかはいずれも針葉樹で，特に *Abies, Tsuga, Picea* が多産しており，この結果は，葉化石では広葉樹が主体をなし，針葉樹が少ないこととは大きく異なっている．その理由として鈴木三男（1973）は次のように述べている．すなわち，葉化石は湖の岸辺に生育する木々の葉が湖岸に近い波静かで水の停留するような湖底に堆積してできたものである．一方，材化石は主として亜高山針葉樹林帯に相当する森林の材が洪水，山津波，火山活動などにより押し流されるなどして湖に運ばれた結果であり，葉化石と材化石の産出傾向の違いはこのような堆積機構の差にあると結論している．

これまでに報告されている植物化石は主として塩原町木の葉化石園内に露出している塩原層群から採集されたものである．木の葉化石園では，1905年（明治38年）から化石の採掘が続けられている．この化石園で長年化石の採掘に携わってきた加藤信吉氏（故人）は，生前，「層準により含まれている化石の内容が少し異なる場合があった」と述べていたが，残念ながらそれらの具体的な記録は残されていない．これを実証するために，尾上（1984）は塩原層群堆積当時の環境変化について花粉化石による予察的研究を行った．その結果，塩原層群堆積時，塩原化石湖周辺において植生に変化のあったことが明らかとなった．

塩原層群からは，植物化石ばかりでなく，魚，昆虫，蛙などの化石も共に産している．魚の化石については上野（1967）がウグイに同定した．しかし，ウグイは現在北海道から九州まで分布しているので，この化石から堆積当時の気候についての推論はできないとしている．

また，昆虫の化石については FUJIYAMA（1968, 1969, 1979, 1983）がセミとチョウの化石を報告しており，蛙の化石（中塩原シラン沢産）は SHIKAMA（1955）によって新種として記載されている．田山（1929）は塩原盆地に発達する段丘を調査し，箒川及びその支流に沿って3段の段丘を区別して，それらの形成時期はローム層堆積前の更新世であるとした．郷原ほか（1952）は塩原層群の成因について多方面から解析し，その中で堆積盆となった塩原化石湖の形成は高原火山の活動と密接に関係し，湖は河川が溶岩・集塊岩によってせき止められて生成したものと推察している．

塩原盆地内には温泉試錐調査による資料が豊富で，それらをもとにした地下地質の研究も行われている（鈴木陽雄，1972；鈴木陽雄ほか，1978；栃木県，1971，1978）．これらによると，湖盆の最深部は盆地のほぼ中央の宮島付近にあって，塩原層群の最大層厚は約400 mと推定されている．その中で植物化石の主な産出層準は上部に当たる．

山崎（1975）は塩原層群に含まれている炭化木片の^{14}C絶対年代の測定を行い，約3万年前という値を示している．

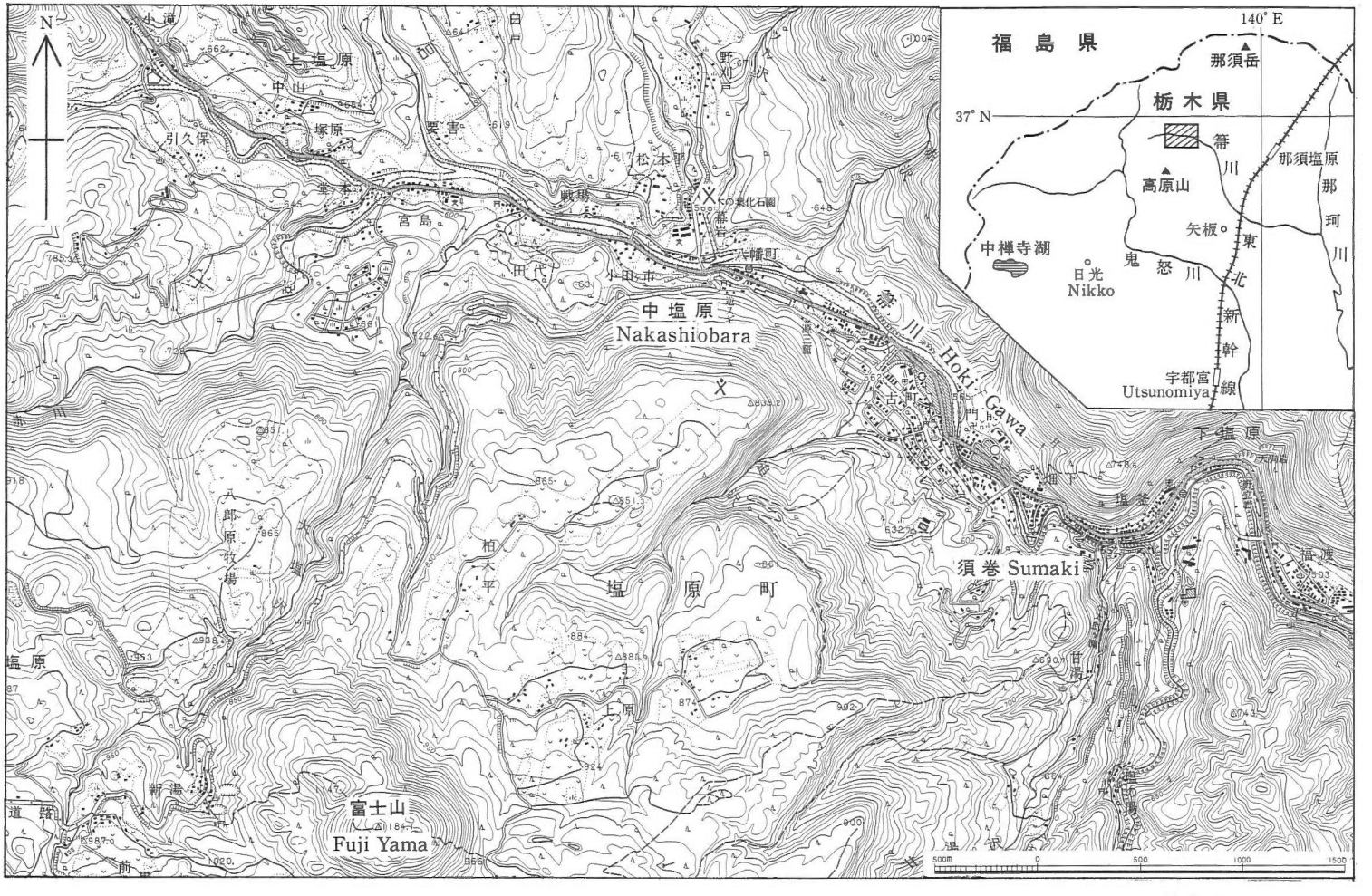
III．化石産地周辺の現在の環境

III.1　位置及び交通

塩原化石植物群を産する塩原盆地は栃木県北部にあって日光国立公園の一角を占めている．交通の便は比較的良く，東北本線西那須野駅又は東北新幹線那須塩原駅からバスが頻繁にでており，約50分で町の中心地塩原温泉駅まで行くことができる．　植物化石の主な産地は塩原温泉駅の北西約1.5 km，中塩原の木の葉化石園（北緯36度58分48秒，東経139度48分35秒，標高580 m）内にある（第1図）．塩原盆地は国土地理院発行の5万分の1地形図「塩原」図幅地域の北西部に位置している．

III.2　気　　候

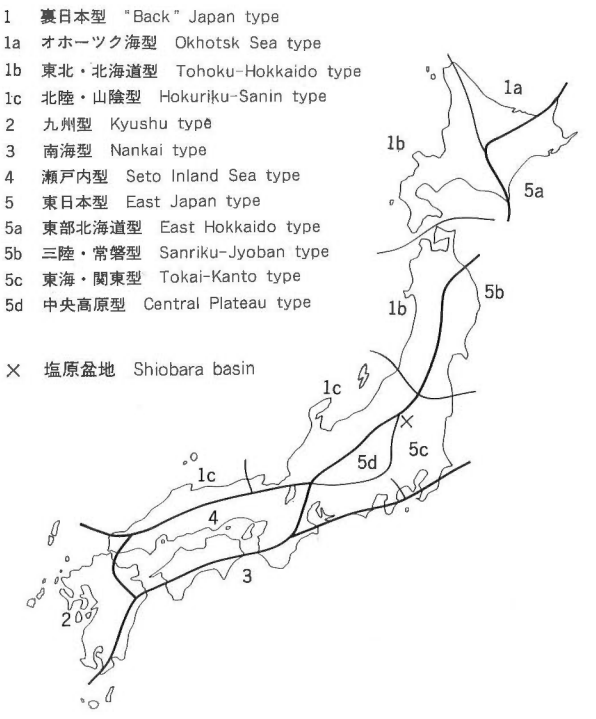
本州の気候は脊梁山脈を挟んで太平洋側と日本海側で大きく異なり，太平洋側は表日本型気候，日本海側は裏日本型気候と呼ばれている．さらに，第2図に示したように地域的な特徴によって気候区が分けられ，塩原盆地は東日本型の東海・関東型に属している（関口，1959）．関東地方は，寒期に北西季節風が強く吹き，乾燥した晴天が多く，暖期に降水量が多いなど表日本型の特徴を有している．しか



第1図　植物化石産地位置図.（国土地理院 1985 年発行　2万5千分の1地形図「塩原」の一部を使用）

Fig. 1　Map showing the fossil locality.

X 植物化石産地
Plant fossil locality



第2図　日本の気候区分.（関口，1959による）
Fig. 2　Climatic regions in Japan. (After SEKIGUCHI, 1959)

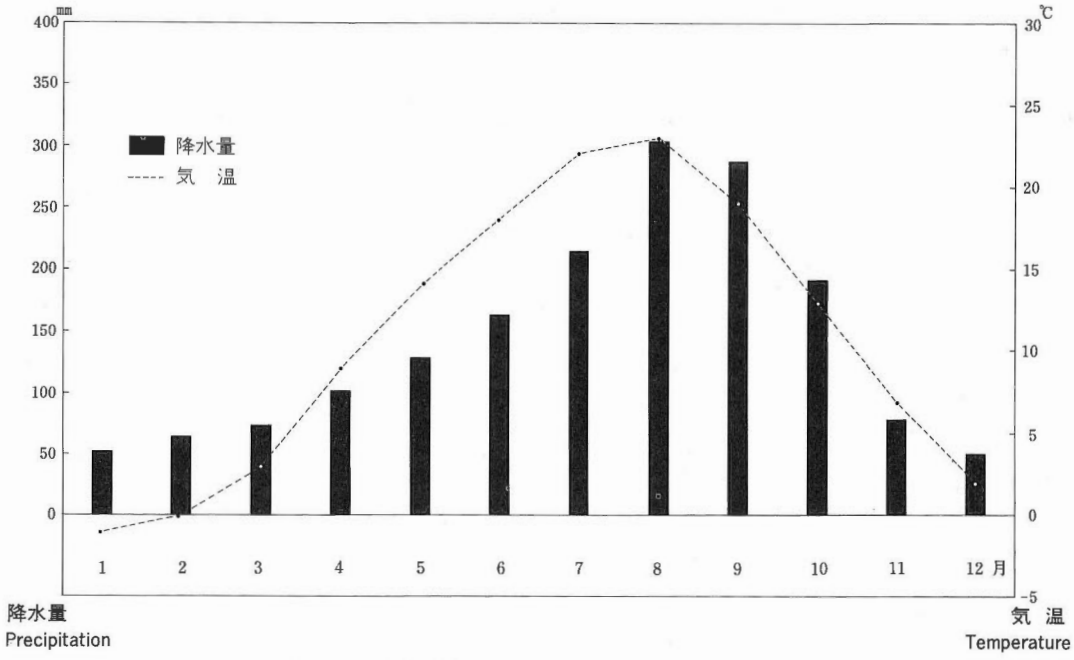
し，塩原盆地周辺は，同じ関東地方でも北部山岳地域に位置しており，北に東北地方の三陸・常磐型気候，そして西に裏日本型の気候を示す地域が隣接している地理的条件のため，次に述べるように東海・関東型と言っても太平洋に直接面している地域とはやや異なった気候を示している．

第1表及び第3図に示したとおり，塩原盆地では降水量が夏季に多く冬季に少ない傾向がある．8月，9月には雷雨が多く，したがって降水量も極端に多くなり，この2か月で年降水量の約3分の1に達する．一方，12月から3月にかけては，北西の季節風によって日本海側の降雪がしばしば吹き込み，年平均20日間の降雪日があり，積雪が50 cmを超えることもある．このように塩原盆地の気候は，多少裏日本型気候の影響も受けているが，大局的には表日本型を示している．塩原盆地の気象記録（宇都宮地方気象台，1963）による年平均気温は10.5°C，年平均降水量は1,706.1 mmであり，また，月別平均気温から算出された“暖かさの指数”（吉良，1949）は81.9°Cで，日本の冷温帯林を代表するブナ林の生育に好適な条件を示している．

第1表　塩原気象観測所における気温及び降水量の記録.（1911年～1960年　50年平均）
Table 1　50 years (1911～1960) mean temperature and precipitation in the Shiobara basin.

［宇都宮地方気象台編（1963）による］

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual mean
Temperature (°C)	−1.0	−0.3	3.2	8.5	13.6	17.6	21.6	22.5	18.5	12.5	7.1	2.4	10.5
Precipitation (mm)	51.8	63.7	74.0	102.2	128.0	162.8	215.0	303.8	287.1	190.7	77.6	49.6	1,706.1



第3図 塩原盆地の気温・降水量年変化.
Fig. 3 Annual variation of mean temperature and precipitation in the Shiobara basin.

III.3 植　生

日本の植物帯は，日本列島全体が湿潤気候であるため，気温の違いによる温度植生帯としてその中を区分することができる．すなわち，針葉樹を主体とする亜寒帯（亜高山帯），落葉広葉樹を主体とする冷温帯（山地帯），常緑広葉樹を多く含む暖温帯（低地帯）そして亜熱帯林を主体とする亜熱帯である．更に，我が国の森林植生は，降水量が冬に多い裏日本と，夏に多い表日本とで生育する植物の組成が異なるので裏日本型と表日本型に区分されている．特に *Fagus crenata*（ブナ）を中心とした冷温帯林に両者の組成上の違いが明瞭にあらわれている．すなわち表日本型のブナ林は，*Fagus japonica*（イヌブナ），*Sasa purpurascens*（スズタケ），*Stewartia pseudo-camellia*（ナツツバキ），*Stewartia monadelpha*（ヒメシャラ），*Lindera umbellata*（クロモジ），*Hamamelis japonica*（マンサク），などを混生する．

一方，裏日本型ではほとんど *Fagus crenata* が純林状に生育し，林床に *Sasa palmata*（チマキザサ），*Sasa kurilensis*（チシマザサ）と常緑低木の *Ilex leucoclada*（ヒメモチ），*Daphniphyllum macropodum*（エゾユズリハ），*Aucuba japonica* var. *borealis*（ヒメアオキ）などが多くみられる．

日本の冷温帯を代表するブナ林は日本列島を中心に北は北海道渡島半島の黒松内低地部から，本州，四国の山地をへて南九州大隅半島の高隈山（1,237 m）の山頂部まで拡がっている．このブナ林は一般に年平均気温が6～13℃，“暖かさの指数”が45～85℃，そして年平均の降水量が約1,200 mm以上といった冷涼で湿潤な気候条件下に分布しており，前述のとおり夏季に雨の多い太平洋側の山地にはブナ—スズタケ型のブナ林が，また，冬季に雪の多い日本海側の山地にはブナ—チシマザサ型のブナ林がそれぞれ発達している．

塩原盆地周辺では，大半が表日本型のブナ林で特徴づけられる種類組成からなっているが，一部，盆地の西方赤川沿いの標高約700 m以上には裏日本型のブナ林が認められている．このように同一盆地内で表日本型のブナ林と裏日本型のブナ林とが近接して分布している事実は，後述する塩原化石植物群の示す組成と共通点があり，注目に値する．

IV. 地形・地質の概説

塩原盆地は，東西約5 km，南北約2 kmの，北に向かって凸な三日月型の小盆地である．盆地底の高度は海抜550～750 mであるが，盆地を取り囲んで東・北及び西には主として新第三系からなる標高1,000～1,500 mの険しい山並が連なっている．盆地の南には，釈迦ヶ岳（1,795 m）をはじめ高原火山の峰々がそびえ，その一部を構成する数枚の厚い安山岩溶岩流からなる山麓斜面が広がっている．盆地のほぼ中央を箒川が西から東へ流れ，盆地の東端，畑下付近から深い峡谷をつくりながらおよそ7 km東流して，関谷付近から那須野ヶ原扇状地の南西縁に沿って流下し，やがて那珂川に合流する．盆地内の箒川沿いには塩原層群を切って数段の段丘がみられる．これらの段丘面は一般におおよそ30/1000の傾斜を示しており，現在の箒川の河床勾配とほぼ一致している（田山，1929；高橋・内田，1956）．

この湖盆の成因に関して，古くは矢部（1929）が「北東—西南方向に長い長方形の陥没凹地」という考え方を提唱し，高原火山初期の噴出はこの陥没に伴って，あるいは引き続いて起こったものと想定した．その後，この凹地あるいは湖の成因として「火山堰止め説」（郷原ほか，1952），あるいは「断層陥没説」（高橋・内田，1956）が提出されている．しかし，今回の研究結果では，後述するように，湖盆はカルデラ湖として存在していたものと考えられる．

塩原周辺の地質図としては，7万5千分の1地質図幅「塩原」（岩生・今井，1955）及び15万分の1「栃木県地質図」（栃木県，1977）などがある．

本報告では，主として岩生・今井（1955）の層序区分に従い，塩原周辺の地質の概要を述べる（第2表・第4図）．

IV.1 先第四系

IV.1.1 中・古生代堆積岩類

塩原地域西方の鬼怒川地域には，かつて“秩父古生層”に属するとされていた古期堆積岩類が広く分布し，「川治層群」と呼ばれている．川治層群の石灰岩レンズから二畳紀のフズリナが，チャートからは三畳紀後期を示すコノドントが報告されている（佐藤，1980）．塩原地域では，盆地南西部の赤川上流で，川治層群の東方延長とみられる砂岩・粘板岩互層が高原火山岩類の下位に小範囲に露出している（岩生・今井，1955）．

IV.1.2 花崗岩類

塩原盆地の西側に普通角閃石黒雲母花崗岩の岩体が点在しているほか，一部に石英閃緑岩が小岩体として見られる．これら花崗岩類の地質年代については確固たる証拠はないが，白亜紀—古第三紀のものと考えられている．

IV.1.3 新第三系

塩原地域では，先新第三紀基盤岩類を不整合に覆い，いわゆる緑色凝灰岩で特徴づけられる厚い海底火山噴出物を主体とする地層が広く分布し，3層群に区分されている．

下部の福渡層群は主として緑色凝灰岩からなり，盆地の北側を取り巻いている．中部の鹿股沢層群は，福渡層群を整合に覆い，主として盆地の東側に分布している．本層は砂岩・泥岩及び凝灰岩からなる海成層で，貝化石を多産する（YOKOYAMA, 1926）．これらは塩原型動物群と呼ばれ，中新世中－後期（女川期）の浅海砂底の貝化石群を代表するものである（鎮西，1981）．鹿股沢層群の上には，亜炭や植物化石を挟在する砂岩・泥岩及び凝灰岩からなる関谷層群が整合関係で載っている．同層群は塩原地域の山地東縁（鬼怒川地溝の西縁）に沿って南北方向に帯状の分布を示し，東へ急傾斜している地層で，塩原盆地内でその分布は確認されていない．

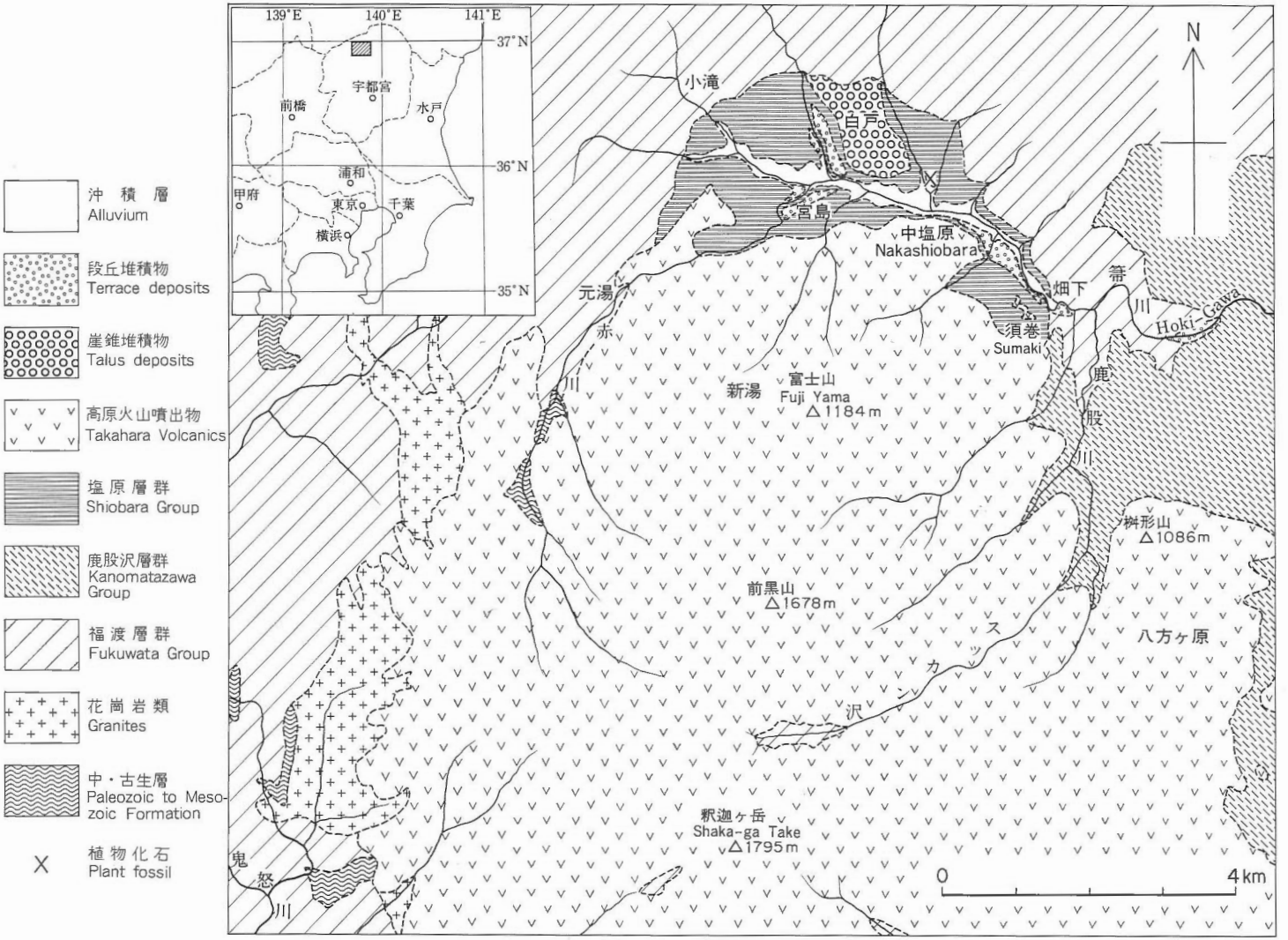
第2表　塩原周辺地域層序比較表.
Table 2　Stratigraphic sequence of the Shiobara area.

AKUTSU (1964)			尾上 (1989)**	
完新世 Holocene	石灰沈殿物 Calcareous sinter		完新世 Holocene	河床堆積物・石灰沈殿物 River bed deposits · Calcareous sinter
上部更新世 Upper Pleistocene	ローム層 Loam Formation		更新世 Pleistocene	段丘礫層・崖錐堆積物・ローム層 Terrace gravel · Talus deposits · Loam Formation
	段丘礫層・崖錐堆積物 Terrace gravel · Talus deposits			
下部更新世 Lower Pleistocene	塩原層群 Shiobara Group	赤川層・塩原溶岩 Akagawa Formation · Shiobara Lava		塩原層群* Shiobara Group / 高原火山噴出物 Takahara Volcanics
		宮島層* Miyajima Formation		
		中塩原火山角礫岩 Nakashiobara Volcanic Breccia		
		須巻層* Sumaki Formation		
		古町礫岩 Furumachi Conglomerate		
	塩谷層群及びシラン沢石英斑岩 Shioya Group and Shiranzawa Quartz-porphyry		中新世 Miocene	(関谷層群) (Sekiya Group)
				鹿股沢層群 Kanomatazawa Group
				福渡層群 Fukuwata Group
			白亜紀-古第三紀 Cretaceous to Paleogene	(花崗岩類) (Granites)
			中・古生代 Paleozoic to Mesozoic	川治層群 Kawaji Group

* 植物化石産出層準
Plant-bearing stratum

** 中新世以前は岩生・今井 (1955) による
The sequence of Miocene and older formations are cited from IWAO and IMAI (1955)

( ) 塩原盆地内に分布していない
Not distributed in the Shiobara basin



〔主として岩生・今井(1955)による〕

第4図　塩原盆地及びその周辺地域地質概略図.

Fig. 4　Geologic map of the Shiobara area. (modified after IWAO and IMAI, 1955)

IV.2　塩原層群（更新統）

塩原層群は，湖盆底を形成する主として新第三系基盤岩類を不整合に覆い，段丘礫層・崖錐堆積物及び高原火山噴出物によって覆われている．また，本層群中には高原火山の溶岩流が基底部をはじめとして数枚挟まれている．このように，湖盆の発生と本層群の堆積は高原火山の，特にその初期の活動［池島・青木（1962）の高原火山の第1期の活動］と同時期である．

本層群はAKUTSU（1964）によって下位から古町礫岩・須巻層・中塩原火山角礫岩・宮島層・赤川層の5累層に区分されてきた（第2表）．それによると，地表調査で得た柱状図から得られる塩原層群の層厚は約310 mであるが，豊富にある温泉試錐の資料によると，湖盆の最深部は宮島付近にあって，そこでの全層厚はおおよそ400 mに達している．

須巻・宮島及び赤川の3累層は，一般に湖盆の周縁相である砂礫相から中心相である泥質相への側方変化が顕著である．この二つの相は同時異相の関係にあり，典型的な小湖水域の堆積相を示している．

AKUTSU（1964）が中塩原火山角礫岩と呼んだ岩体は今日の知見では安山岩の自破砕溶岩流であって，塩原盆地の東縁須巻付近と盆地の中央部中塩原の2地点のみで確認できる．AKUTSU（1964）は，この“火山角礫岩”は塩原層群の泥岩中に介在し，下位の須巻層と上位の宮島層を境すると考えた．しかし，須巻における溶岩流と塩原層群が接触している露頭（第5図）の観察によると，

1）　溶岩流の先端部は破砕されており，その間隙は塩原層群の泥岩によって埋められている．

2）　破砕部分を含めた溶岩流の先端部は全体にガラス質で，細かい節理が発達していることから，この溶岩流は水に接して急速に冷却し，固結したものと考えられる．

3）　溶岩流の先端から約2 mの間の泥層が押し曲げられたような複雑な構造を示している．

4）　溶岩流の上位の地層はほぼ水平に堆積しており，もめていない．

以上の特徴から須巻の岩体は貫入岩体ではなく，塩原層群の堆積中に湖盆中に流入した溶岩流と判断される．一方，中塩原の岩体は塩原層群を覆って分布している溶岩流であって，この溶岩流の上位に湖底堆積物は認められない．また，多くの地点の試錐資料から塩原層群中には数枚の安山岩溶岩流が存在することが確認されている（鈴木陽雄，1972；鈴木陽雄ほか，1978；栃木県，1978）．池島・青木（1962）はこれら溶岩流が高原火山の第1期の活動の産物であり，塩原層群と指交関係にあることを指摘している．

すなわち，須巻及び中塩原の溶岩流は何回か繰り返された高原火山からの溶岩流出のそれぞれわずかずつ異なった活動期のものであって，岩相，岩質は互いによく類似するが，湖盆全体にわたって一様に分布しているわけではない．したがって，AKUTSUが“中塩原火山角礫岩”とした溶岩流は同一層準を示す鍵層となりえず，塩原層群中の泥岩層を須巻層と宮島層とに区分することはできない．

また，主として砂礫岩からなる赤川層と主として泥質岩からなる「須巻層及び宮島層」との関係については，部分的に上下の関係も見られるが，前述のように塩原層群は全体を通じて泥質相と砂礫相の側方変化が極めて著るしく，上下に岩相の変化する部位が必ずしも同時面を意味しない．この現象は，現在の火山地帯の湖沼群でもしばしば観察されるように，泥質部と砂礫部との分布の変動は，山体浸食による原物質の供給量の変化，水量，水面標高，流入小河川の流路の局所的変動など，偶然の要因に支配された小規模な堆積環境の変化によって引き起こされる事例が多く，本格的な地殻変動を反映した層相変化とは言いがたい．

これらを総合して，本研究では湖盆と堆積物の形成史という視点から，AKUTSUの累層区分によらず，岩生・今井（1955）にならって「塩原層群」として一括して表現することとする．

塩原盆地のほぼ中央の中塩原，宮島周辺には，白色・灰色などの0.5～数mm単位の葉理を示す珪藻質泥岩（シルト岩と粘土岩の細互層）の珪化した硬い層と無葉理で大型化石を含まないシルト質泥岩の互層が発達しており，珪藻質泥岩の葉理面に沿って多量の植物化石をはじめ昆虫，魚，蛙などの保存良好な化石を産する．本研究で取り扱っている植物化石はこの層準［AKUTSU（1964）の宮島層］から採集されたもので塩原層群の上部にあたる．

後述するように，塩原層群上部の形成年代は，本層と指交関係にある高原火山噴出物の絶対年代測定

第5図　高原火山溶岩流と塩原層群の接触面.
Fig. 5　Mudstone member of the Shiobara Group compressed by lavaflow of the Takahara Volcano.

結果から0.3 Maと推定できる．

IV.3　高原火山（更新統）

高原火山は東日本火山帯（那須火山帯）に属し，北部を占める塩原火山と南部を占める釈迦ヶ岳とが複合した火山であるとされている（池島・青木，1962）．

高原火山の基盤は中・古生層，白亜紀―古第三紀花崗岩類及び新第三紀層からなっている．中・古生層と花崗岩類は高原火山の西部と南部に露出し，新第三紀層は東部及び北部に広く分布している．これら火山の基盤が赤川上流や鹿股川上流のスッカン沢などで塩原の盆地底よりはるかに高所で見いだされている（岩生・今井，1955）ことは注目に値する．

高原火山の最初期の噴出物である大田原軽石流堆積物は，高原火山の東～東南方の足尾山地と八溝山地とに挟まれた鬼怒川地溝に，約700 km²にわたって広がっている（第6図）．この軽石流の層厚を平均50 m程度とすれば，その体積はおよそ35 km³と見積られる．おそらく，このような大量の軽石流の噴出によってカルデラが生じ，その内側に生じた淡水湖が塩原層群の堆積の場となったものであろう．

現在みられる火山の基盤の分布からも，第7図に示したようなカルデラの存在が予想される．温泉試錐の結果では木の葉化石園では海抜300 mで基盤に達することが知られており，須巻付近では海抜330 mでなお基盤に達していない．また，これまでの試錐記録のうち深い基盤を示す例としては宮島付近の海抜175 m，192 m及び233 mなどがある（鈴木陽雄ほか，1978；栃木県，1978）．

カルデラ形成後，カルデラ南縁部を中心として火山活動が起こり，主として安山岩からなる高原火山の山体を形成した．小池ほか（1985）によると，栃木県塩谷郡氏家町根本付近に分布する大田原軽石流堆積物の下位の戸祭ローム層は，ジルコンによるフィッション・トラック年代測定の結果約50万年前という値が報告されている．

また，高原火山の溶岩流のうち，同火山の北麓を構成し，塩原層群上部中に挟在したり同層群を覆ったりしている数枚の安山岩溶岩についてK-Ar法による全岩年代測定を行った結果，およそ30万年前という値が示された（板谷ほか，未公表資料）．なお，高原火山の側火山である富士山の溶岩円頂丘の西側に当たる新湯では現在でも微弱な硫気活動が続いている．

IV.4　新期堆積物（更新統―完新統）

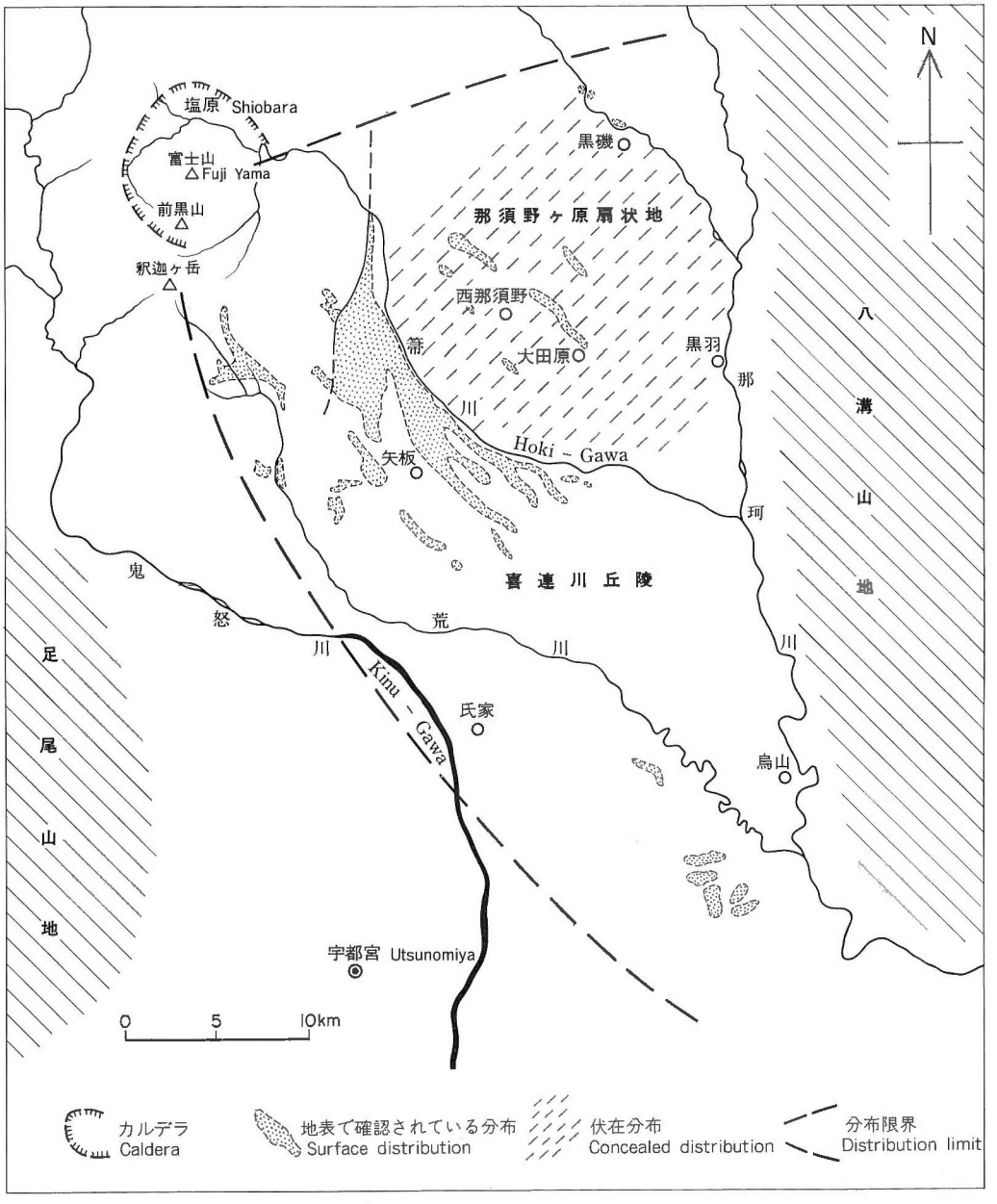
塩原盆地内の箒川及び同支流の河岸には段丘の発達が見られ，おおよそ4段に識別される．それらは，低位のもの（完新世の形成）を除いて，新期の火山灰層に覆われている．高位の段丘（中山上位段丘）は，被覆ロームの層序に基づいて，更新世後期の那須野中位面（岩崎ほか，1984 a, b）に対比されている（早川ほか，1985）．これら段丘は，すべて扇状地性の粗大な礫層によって構成されている．

盆地の北部付近には崖錐堆積物が見られるほか，源三窟，門前，古町地区には温泉水起源の石灰沈殿物の小規模な分布がある（栃木県，1971；山崎，1974）．

V．化石植物群の構成

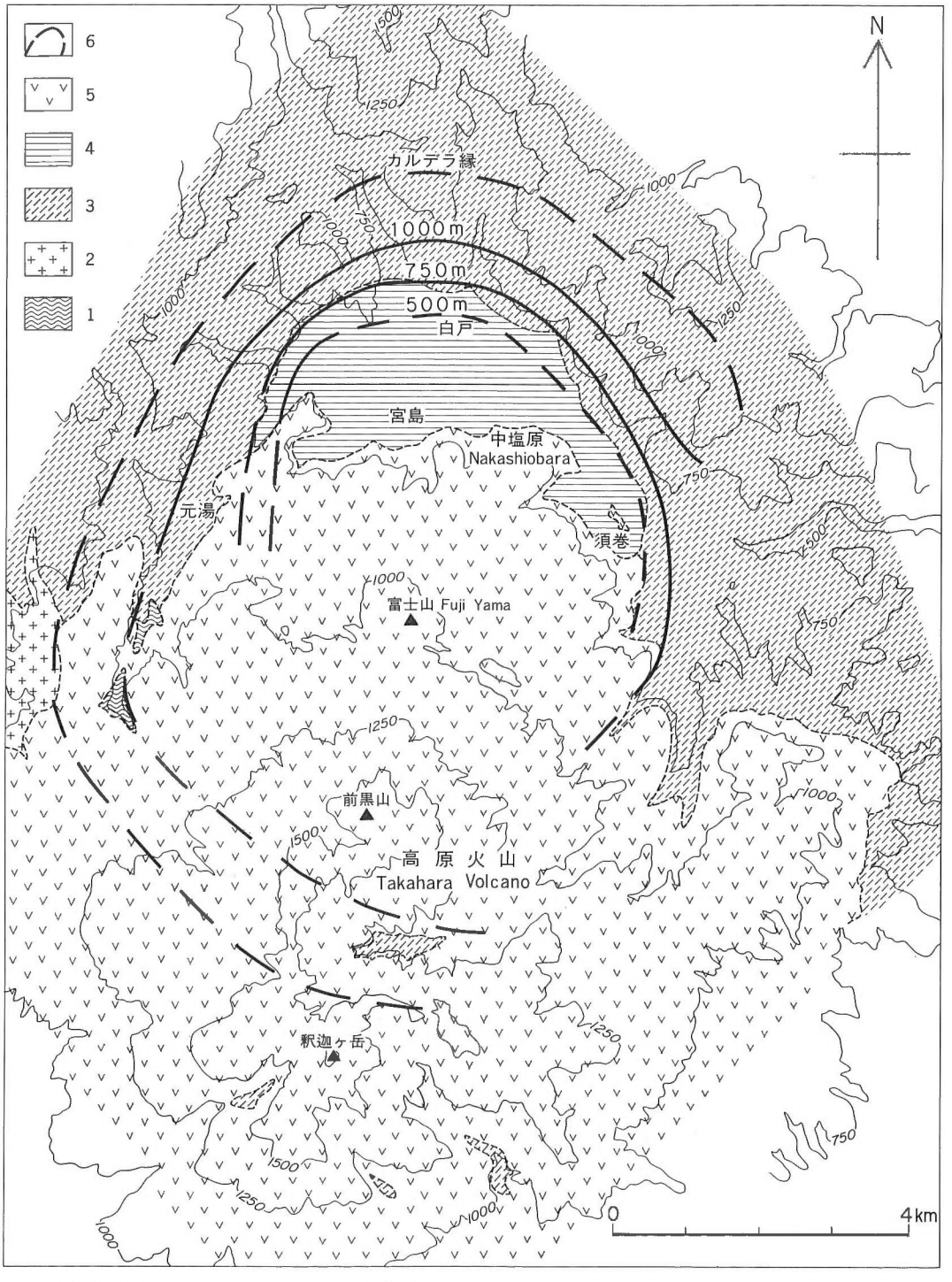
V.1　大型化石（葉・実・花など）

今回の研究対象となった大型化石標本は11,494点である．その大半は筆者が塩原町中塩原の木の葉化石園露頭から採集した標本及び同園所蔵の標本からなるが，加えて，遠藤によって研究され東北大学理学部地質学古生物学教室に保存されている標本，小泉（1940）によって研究され，京都大学理学部植物教室に所蔵されている標本並びに尾崎公彦によって採集された横浜国立大学の標本についても検討する機会を得た．産状からみてこれらの標本はすべて同一の母集団に属するものと解釈できる．



第6図　大田原軽石流分布図．(Akutsu (1964)；池島・青木 (1962)；岩生・今井 (1955)；中村ほか (1980)；佐々木ほか (1958)；鈴木 (1952, 1955)；鈴木・阿久津 (1955)；渡部・堤橋 (1957, 1960, 1962)；渡部ほか (1960) をもとに編集)

Fig. 6　Distribution of the Otawara pumice flow. (Compiled from AKUTSU (1964) etc.)



1 中・古生層
Paleozoic to Mesozoic Formation

2 花崗岩類
Granites

3 新第三紀層
Neogene Formation

4 塩原層群(新期堆積物を除く)
Shiobara Group
(Younger deposits are omitted)

5 高原火山噴出物
Takahara Volcanics

6 カルデラ内壁の等高線及びカルデラ縁
Contour of caldera wall and rim

第7図　予想されるカルデラ地形.
Fig. 7　Map showing an assumed topography of caldera.

第3表　塩原化石植物群大型化石一覧表

Table 3　Systematic list of the Shiobara fossil flora (macrofossil)

PTERIDOPHYTA　シダ植物

Davalliaceae　シノブ科

Davallia mariesii MOORE　シノブ

Aspidiaceae　オシダ科

Athyrium yokoscense (FRANCHET et SAVATIER) CHRIST　ヘビノネゴザ

Polystichum tripteron (KUNZE) PRESL　ジュウモンジシダ

Woodsia manchuriensis HOOKER　フクロシダ

Woodsia polystichoides EATON　イワデンダ

Blechnaceae　シシガシラ科

Blechnum amabile MAKINO　オサシダ

SPERMATOPHYTA　種子植物

GYMNOSPERMAE　裸子植物

Pinaceae　マツ科

Abies firma SIEBOLD et ZUCCARINI　モミ

Larix leptolepis (SIEBOLD et ZUCCARINI) GORDON　カラマツ

Picea polita (SIEBOLD et ZUCCARINI) CARRIERE　ハリモミ

Pinus parviflora SIEBOLD et ZUCCARINI　ヒメコマツ

Tsuga sieboldii CARRIERE　ツガ

Taxodiaceae　スギ科

Cryptomeria japonica D. DON　スギ

Cupressaceae　ヒノキ科

Chamaecyparis pisifera (SIEBOLD et ZUCCARINI) SIEBOLD et ZUCCARINI　サワラ

Juniperus rigida SIEBOLD et ZUCCARINI　ネズ

Thuja standishii (GORDON) CARRIERE　クロベ

ANGIOSPERMAE　被子植物

Juglandaceae　クルミ科

Juglans ailanthifolia CARRIERE　オニグルミ

Pterocarya rhoifolia SIEBOLD et ZUCCARINI　サワグルミ

Salicaceae　ヤナギ科

Populus maximowiczii HENRY　ドロノキ

Populus sieboldii MIQUEL　ヤマナラシ

Salix integra THUNBERG　イヌコリヤナギ

Salix sachalinensis FR. SCHMIDT　オノエヤナギ

Betulaceae　カバノキ科

Alnus firma SIEBOLD et ZUCCARINI　ヤシャブシ

Alnus hirsuta var. *sibirica* (FISCHER) C. K. SCHNEIDER　ヤマハンノキ

Alnus maximowiczii CALLIER　ミヤマハンノキ

Alnus pendula MATSUMURA　ヒメヤシャブシ

Alnus sp. (fruit)*　ハンノキ属の1種(果実)

Betula davurica PALLAS ヤエガワカンバ

Betula ermani CHAMISSO ダケカンバ

Betula grossa SIEBOLD et ZUCCARINI ミズメ

Betula maximowicziana REGEL ウダイカンバ

Betula nikoensis KOIDZUMI マカンバ

Betula platyphylla var. *japonica* (MIQUEL) HARA シラカンバ

Betula schmidtii REGEL オノオレカンバ

Betula sp. (ament)* カバノキ属の1種(尾状花序)

Carpinus cordata BLUME サワシバ

Carpinus japonica BLUME クマシデ

Carpinus laxiflora (SIEBOLD et ZUCCARINI) BLUME アカシデ

Carpinus tschonoskii MAXIMOWICZ イヌシデ

Corylus sieboldiana BLUME ツノハシバミ

Fagaceae ブナ科

Castanea crenata SIEBOLD et ZUCCARINI クリ

Fagus crenata BLUME ブナ

Fagus japonica MAXIMOWICZ イヌブナ

Quercus aliena BLUME ナラガシワ

Quercus mongolica var. *grosseserrata* (BLUME) REHDER et WILSON ミズナラ

Quercus serrata THUNBERG コナラ

Ulmaceae ニレ科

Celtis jessoensis KOIDZUMI エゾエノキ

Ulmus davidiana var. *japonica* (REHDER) NAKAI ハルニレ

Ulmus laciniata (TRAUTVETTER) MAYR オヒョウ

Moraceae クワ科

Cudrania tricuspidata (CARRIERE) BUREAU ハリグワ

Morus bombycis KOIDZUMI ヤマグワ

Urticaceae イラクサ科

Boehmeria tricuspis (HANCE) MAKINO アカソ

Polygonaceae タデ科

Polygonum cuspidatum SIEBOLD et ZUCCARINI イタドリ

Magnoliaceae モクレン科

Magnolia obovata THUNBERG ホオノキ

Lauraceae クスノキ科

Lindera membranacea MAXIMOWICZ オオバクロモジ

Lindera obtusiloba BLUME ダンコウバイ

Lindera umbellata THUNBERG クロモジ

Parabenzoin praecox (SIEBOLD et ZUCCARINI)NAKAI アブラチャン

Trochodendraceae ヤマグルマ科

Trochodendron aralioides SIEBOLD et ZUCCARINI ヤマグルマ

Trochodendron aralioides var. *longifolium* (MAXIMOWICZ) OHWI ナガバノヤマグルマ

Eupteleaceae フサザクラ科

Euptelea polyandra SIEBOLD et ZUCCARINI フサザクラ

Cercidiphyllaceae カツラ科

Cercidiphyllum japonicum SIEBOLD et ZUCCARINI カツラ

Cercidiphyllum magnificum (NAKAI) NAKAI ヒロハカツラ

Ranunculaceae キンポウゲ科

Clematis apiifolia DE CANDOLLE ボタンズル

Clematis apiifolia var. *biternata* MAKINO コボタンズル

Berberidaceae メギ科

Berberis amurensis var. *japonica* (REGEL) REHDER ヒロハヘビノボラズ

Ceratophyllaceae マツモ科

Ceratophyllum demersum LINNAEUS マツモ

Actinidiaceae マタタビ科

Actinidia arguta (SIEBOLD et ZUCCARINI) PLANCHON ex MIQUEL サルナシ

Actinidia polygama (SIEBOLD et ZUCCARINI) MAXIMOWICZ マタタビ

Theaceae ツバキ科

Stewartia pseudo-camellia MAXIMOWICZ ナツツバキ

Hamamelidaceae マンサク科

Corylopsis gotoana MAKINO ミヤマトサミズキ

Hamamelis japonica SIEBOLD et ZUCCARINI マンサク

Hamamelis japonica var. *obtusata* MATSUMURA マルバマンサク

Hamamelis megalophylla KOIDZUMI オオバマンサク

Saxifragaceae ユキノシタ科

Cardiandra alternifolia SIEBOLD et ZUCCARINI クサアジサイ

Deutzia scabra THUNBERG ウツギ

Hydrangea hirta (THUNBERG) SIEBOLD コアジサイ

Hydrangea paniculata SIEBOLD ノリウツギ

Hydrangea petiolaris SIEBOLD et ZUCCARINI ツルアジサイ

Philadelphus satsumanus SIEBOLD バイカウツギ

Ribes ambiguum MAXIMOWICZ ヤシャビシャク

Ribes fasciculatum SIEBOLD et ZUCCARINI ヤブサンザシ

Rodgersia podophylla A. GRAY ヤグルマソウ

Saxifraga fortunei HOOKER ダイモンジソウ

Schizophragma hydrangeoides SIEBOLD et ZUCCARINI イワガラミ

Rosaceae バラ科

Aruncus sylvester KOSTELETZKY ヤマブキショウマ

Chaenomeles japonica (THUNBERG) LINDLEY クサボケ

Crataegus maximowiczii C. K. SCHNEIDER オオバサンザシ

Kerria japonica (THUNBERG) DE CANDOLLE ヤマブキ

Malus sieboldii (REGEL) REHDER ズミ

Potentilla fragarioides var. *major* MAXIMOWICZ キジムシロ

Pourthiaea villosa (THUNBERG) DECAISNE カマツカ

Prunus apetala (SIEBOLD et ZUCCARINI) FRANCHET et SAVATIER チョウジザクラ

Prunus jamasakura SIEBOLD ex KOIDZUMI ヤマザクラ

Prunus maximowiczii RUPRECHT ミヤマザクラ

Prunus nipponica MATSUMURA ミネザクラ

Prunus sargentii REHDER オオヤマザクラ
Prunus ssiori FR. SCHMIDT シウリザクラ
Pyrus pyrifolia (BURMAN) NAKAI ヤマナシ
Rosa multiflora THUNBERG ノイバラ
Rubus crataegifolius BUNGE クマイチゴ
Rubus palmatus THUNBERG ナガバモミジイチゴ
Rubus sp. キイチゴ属の1種
Sorbus alnifolia (SIEBOLD et ZUCCARINI) C. KOCH アズキナシ
Sorbus commixta HENDLUND ナナカマド
Sorbus gracilis (SIEBOLD et ZUCCARINI) C. KOCH ナンキンナナカマド
Sorbus japonica (DECAISNE) HEDLUND ウラジロノキ
Stephanandra incisa (THUNBERG) ZABEL コゴメウツギ

Leguminosae マメ科
Cladrastis platycarpa (MAXIMOWICZ) MAKINO フジキ
Dumasia truncata SIEBOLD et ZUCCARINI ノササゲ
Gleditsia japonica MIQUEL サイカチ
Maackia amurensis var. *buergeri* (MAXIMOWICZ) C. K. SCHNEIDER イヌエンジュ
Wisteria floribunda (WILLDENOW) DE CANDOLLE フジ

Euphorbiaceae トウダイグサ科
Sapium japonicum (SIEBOLD et ZUCCARINI) PAX et HOFFMANN シラキ

Anacardiaceae ウルシ科
Rhus ambigua LAVALLEE ex DIPPEL ツタウルシ
Rhus trichocarpa MIQUEL ヤマウルシ

Aceraceae カエデ科
Acer crataegifolium SIEBOLD et ZUCCARINI ウリカエデ
Acer diabolicum BLUME ex KOCH カジカエデ
Acer japonicum THUNBERG ハウチワカエデ
Acer micranthum SIEBOLD et ZUCCARINI コミネカエデ
Acer miyabei MAXIMOWICZ クロビイタヤ
Acer mono MAXIMOWICZ イタヤカエデ
Acer mono var. *glaucum* (KOIDZUMI) SUGIYAMA ウラジロイタヤ
Acer mono var. *marmoratum* (NICHOLS) HARA エンコウカエデ
Acer nikoense MAXIMOWICZ メグスリノキ
Acer palmatum THUNBERG イロハモミジ
Acer palmatum var. *amoenum* (CARRIERE) OHWI オオモミジ
Acer rufinerve SIEBOLD et ZUCCARINI ウリハダカエデ
Acer sieboldianum MIQUEL コハウチワカエデ
Acer tenuifolium (KOIDZUMI) KOIDZUMI ヒナウチワカエデ

Hippocastanaceae トチノキ科
Aesculus turbinata BLUME トチノキ

Aquifoliaceae モチノキ科
Ilex macropoda MIQUEL アオハダ

Celastraceae ニシキギ科
Celastrus orbiculatus THUNBERG ツルウメモドキ

Buxaceae ツゲ科

Buxus microphylla var. *japonica* (MUELLER) REHDER et WILSON ツゲ

Rhamnaceae クロウメモドキ科

Berchemia berchemiaefolia (MAKINO) KOIDZUMI ヨコグラノキ

Berchemia racemosa SIEBOLD et ZUCCARINI クマヤナギ

Vitaceae ブドウ科

Parthenocissus tricuspidata (SIEBOLD et ZUCCARINI) PLANCHON ツタ

Vitis coignetiae PULLIAT ヤマブドウ

Vitis flexuosa THUNBERG サンカクヅル

Tiliaceae シナノキ科

Tilia japonica (MIQUEL) SIMONKAI シナノキ

Haloragaceae アリノトウグサ科

Myriophyllum spicatum LINNAEUS ホザキノフサモ

Cornaceae ミズキ科

Cornus controversa HEMSLEY ミズキ

Cornus kousa BUERGER ex MIQUEL ヤマボウシ

Araliaceae ウコギ科

Acanthopanax sciadophylloides FRANCHET et SAVATIER コシアブラ

Aralia cordata THUNBERG ウド

Kalopanax septemlobus (THUNBERG) KOIDZUMI ハリギリ

Clethraceae リョウブ科

Clethra barbinervis SIEBOLD et ZUCCARINI リョウブ

Ericaceae ツツジ科

Enkianthus campanulatus (MIQUEL) NICHOLS サラサドウダン

Lyonia ovalifolia var. *elliptica* (SIEBOLD et ZUCCARINI)HANDEL-MAZZETTI ネジキ

Rhododendron degronianum CARRIERE アズマシャクナゲ

Rhododendron kaempferi PLANCHON ヤマツツジ

Rhododendron quinquefolium BISSET et MOORE ゴヨウツツジ

Rhododendron wadanum MAKINO トウゴクミツバツツジ

Tripetaleia paniculata var. *latifolia* MAXIMOWICZ ホツツジ

Styracaceae エゴノキ科

Pterostyrax hispida SIEBOLD et ZUCCARINI オオバアサガラ

Styrax japonica SIEBOLD et ZUCCARINI エゴノキ

Styrax obassia SIEBOLD et ZUCCARINI ハクウンボク

Oleaceae モクセイ科

Fraxinus lanuginosa KOIDZUMI アオダモ

Ligustrum tschonoskii DECAISNE ミヤマイボタ

Rubiaceae アカネ科

Galium kinuta NAKAI et HARA キヌタソウ

Caprifoliaceae スイカズラ科

Viburnum dilatatum THUNBERG ガマズミ

Viburnum furcatum BLUME オオカメノキ

Viburnum phlebotrichum SIEBOLD et ZUCCARINI オトコヨウゾメ

Viburnum sieboldii MIQUEL ゴマキ

Viburnum wrightii MIQUEL　ミヤマガマズミ

Compositae　キク科

Artemisia princeps PAMPANINI　ヨモギ

Chrysanthemum sp. cf. *C. makinoi* MATSUMURA et NAKAI　リュウノウギクに比較される種

Saussurea sp.　トウヒレン属の1種

Potamogetonaceae　ヒルムシロ科

Potamogeton maackianus A. BENNETT　センニンモ

Potamogeton perfoliatus LINNAEUS　ヒロハノエビモ

Liliaceae　ユリ科

Liliaceae gen. et sp. indet.　ユリ科の1種

Gramineae　イネ科

Sasa sp. cf. *S. kurilensis* (RUPRECT) MAKINO et SHIBATA　チシマザサに比較される種

Sasa sp. cf. *S. palmata* (BEAN) NAKAI　チマキザサに比較される種

Gramineae gen. et sp. indet.　イネ科の1種

* 重複する可能性があるので種の数としては数えない.
In order to avoid double-counting, eliminated from the total of species number.

V.1.1 組　成

塩原化石植物群のうち，葉・実・花などからなる大型化石群は第3表に示したとおり51科104属171種からなっている．最も多くの種数を有する科はRosaceae（バラ科）の13属23種で，次いでBetulaceae（カバノキ科）4属16種，Aceraceae（カエデ科）1属14種，Saxifragaceae（ユキノシタ科）8属11種，Ericaceae（ツツジ科）4属7種，Fagaceae（ブナ科）3属6種，Pinaceae（マツ科）及びLegminosae（マメ科）はそれぞれ5属5種，Caprifoliaceae（スイカズラ科）1属5種，そしてSalicaceae（ヤナギ科），Lauraceae（クスノキ科），Hamamelidaceae（マンサク科）の各2属4種の順となっている．残る科は3種以下で，1種のみからなる科が20科に及んでいる．属においては，*Acer*（カエデ属）の14種が圧倒的に多く，*Betula*（カバノキ属）の7種，*Prunus*（サクラ属）6種，*Viburnum*（ガマズミ属）の5種の順となっている．

これら塩原化石植物群を構成している植物はいずれも現在の北半球に分布している“科”及び“属”からなっており，その分布範囲は亜寒帯から亜熱帯にわたっている．また，今回検討した171種のうち，種まで同定できた167種はすべて現生種で，その大部分は塩原の化石産地を包含する関東地方に分布している．

V.1.2 個体数に基づく量的考察

過去の植生をより的確に解明するためには，産出する植物化石の種数が多いほうが望ましいことは言うまでもないが，合わせて，種ごとの産出個体数が堆積盆地内の植生を復元する上で重要な意味を持つ．したがって，筆者は化石採集現場において，化石の同定を行いながら種別の産出個体数を記録してきた．また，前述のように筆者以外の研究者によって採集されたものでも，筆者が実物を直接検討した標本については，採集標本数に加えて，第4表に示した．

塩原化石植物群を構成している171種のうち，解析の便宜上，個体数で全体の1%（115個体）以上を産するものを取り出して見ると18種で，このうち*Rhododendron wadanum*（トウゴクミツバツツジ）が低木であるほかはいずれも高木からなっており，その化石産出量を合わせると全体の79.6%を占めている．最も産出個体数の多い種は*Fagus crenata*（ブナ）で全体の13%強に達し，次いで*Fagus*

第4表　大型化石の種別産出量

Table 4　Numerical representation of the Shiobara species. (macrofossil)

Species	Number of specimens	Per cent
Fagus crenata (leaves 1,512, cupules 10, nuts 6)	1,528	13.294
Fagus japonica (leaves 1,288, cupules 4, nuts 2)	1,294	11.258
Castanea crenata (leaves 709, burs 3, nuts 3, aments 3)	718	6.247
Betula schmidtii (leaves 643, cone-scales 2, seeds 5)	650	5.655
Quercus mongolica var. *grosseserrata* (leaves 606, nut 1)	607	5.281
Betula grossa (leaves 601, seeds 3, cone-scale 1)	605	5.264
Alnus firma	523	4.550
Stewartia pseudo-camellia	412	3.585
Cercidiphyllum japonicum (leaves 391, seeds 8, fruit 1)	400	3.480
Acer micranthum (leaves 390, samaras 3)	393	3.419
Clethra barbinervis (leaves 389, fruits 3)	392	3.410
Tilia japonica (leaves 355, fruits 3)	358	3.115
Sorbus alnifolia	288	2.506
Acer japonicum (leaves 271, samaras 6)	277	2.410
Lyonia ovalifolia var. *elliptica*	243	2.114
Rhododendron wadanum	186	1.618
Ulmus davidiana var. *japonica* (leaves 154, samara 1)	155	1.349
Carpinus japonica (leaves 112, bracts 9)	121	1.053
Acer rufinerve (leaves 95, samara 7)	102	0.887
Trochodendron aralioides (leaves 85, fruits 3)	88	0.766
Cornus kousa	88	0.766
Hamamelis japonica (leaves 86, fruit 1)	87	0.757
Pourthiaea villosa	85	0.740
Sorbus commixta	84	0.731
Enkianthus campanulatus	84	0.731
Rhododendron kaempferi	82	0.713
Alnus hirsuta var. *sibirica*	80	0.696
Hydrangea paniculata (leaves 69, ornamental flowers 9)	78	0.679
Viburnum furcatum	76	0.661
Myriophyllum spicatum	75	0.653
Fraxinus lanuginosa (leaves 72, fruits 3)	75	0.653
Magnolia obovata	70	0.609
Rhododendron degronianum	68	0.592
Rhododendron quinquefolium	65	0.566
Acer mono (leaves 52, samara 4)	56	0.487
Carpinus cordata (leaves 48, bracts 5)	53	0.461

第4表　(つづき)
Table 4　(continued)

Species	Number of specimens	Per cent
Ceratophyllum demersum	45	0.392
Thuja standishii (leafy shoots 43, cones 2)	45	0.392
Pterocarya rhoifolia (leaflets 35, nut 1)	36	0.313
Celtis jessoensis	35	0.305
Lindera obtusiloba	35	0.305
Acer nikoense (leaflets 34, samara 1)	35	0.305
Sorbus japonica	32	0.278
Quercus serrata	31	0.270
Buxus microphylla var. *japonica* (leaves 26, fruit 1)	27	0.235
Picea polita (foliage shoots 3, seeds 19, cone-scale 1)	23	0.200
Tsuga sieboldii	22	0.191
Viburnum sieboldii	20	0.174
Carpinus laxiflora (leaves 11, bracts 7)	18	0.157
Actinidia arguta	18	0.157
Corylopsis gotoana	18	0.157
Prunus jamasakura	18	0.157
Kalopanax septemlobus	18	0.157
Woodsia polystichoides	15	0.130
Betula maximowicziana (leaves 6, cone-scales 2, seeds 7)	15	0.130
Acer palmatum var. *amoenum*	15	0.130
Berchemia berchemiaefolia	15	0.130
Cornus controversa	15	0.130
Corylus sieboldiana	14	0.122
Pinus parviflora (leaves 8, seeds 3, cone 1)	12	0.104
Rhus trichocarpa (leaflets 11, fruit 1)	12	0.104
Berchemia racemosa	12	0.104
Acanthopanax sciadophylloides	12	0.104
Styrax japonica	12	0.104
Davallia mariesii	11	0.096
Gleditsia japonica	11	0.096
Viburnum dilatatum (leaves 10, fruitng shoot 1)	11	0.096
Acer diabolicum (leaves 7, samaras 3)	10	0.087
Woodsia manchuriensis	8	0.069
Alnus pendula	8	0.069
Rosa multiflora	8	0.069
Tripetaleia paniculata var. *latifolia*	8	0.069

第4表　（つづき）
Table 4　(continued)

Species	Number of specimens	Per cent
Viburnum wrightii	8	0.069
Larix leptolepis (leaves 5, shoot with leaves and cone 1)	6	0.052
Stephanandra incisa	6	0.052
Acer miyabei (leaves 3, samara 3)	6	0.052
Salix sachalinensis	5	0.043
Alnus sp. (fruits)	5	0.043
Betula davurica	5	0.043
Betula nikoensis	5	0.043
Parabenzoin praecox	5	0.043
Trochodendron aralioides var. *longifolium*	5	0.043
Cladrastis platycarpa (legumes)	5	0.043
Wisteria floribunda	5	0.043
Athyrium yokoscense	4	0.035
Populus sieboldii	4	0.035
Cudrania tricuspidata	4	0.035
Euptelea polyandra (leaves 3, samara 1)	4	0.035
Hamamelis megalophylla	4	0.035
Crataegus maximowiczii	4	0.035
Pyrus pyrifolia	4	0.035
Maackia amurensis var. *buergeri*	4	0.035
Artemisia princeps	4	0.035
Abies firma (foliage shoots 2, cone 1)	3	0.026
Betula sp. (aments)	3	0.026
Carpinus tschonoskii (leaves 2, bract 1)	3	0.026
Ulmus laciniata	3	0.026
Lindera umbellata	3	0.026
Clematis apiifolia	3	0.026
Actinidia polygama	3	0.026
Hamamelis japonica var. *obtusata*	3	0.026
Ribes fasciculatum	3	0.026
Saxifraga fortunei	3	0.026
Chaenomeles japonica	3	0.026
Malus sieboldii	3	0.026
Prunus apetala	3	0.026
Prunus maximowiczii	3	0.026
Prunus sargentii	3	0.026

第4表　（つづき）
Table 4　(continued)

Species	Number of specimens	Per cent
Rubus palmatus	3	0.026
Rhus ambigua	3	0.026
Acer mono var. *glaucum*	3	0.026
Ilex macropoda	3	0.026
Parthenocissus tricuspidata	3	0.026
Galium kinuta	3	0.026
Viburnum phlebotrichum	3	0.026
Potamogeton maackianus	3	0.026
Sasa sp. cf. *S. palmata*	3	0.026
Chamaecyparis pisifera	2	0.017
Betula ermani	2	0.017
Boehmeria tricuspis	2	0.017
Cercidiphyllum magnificum	2	0.017
Deutzia scabra	2	0.017
Hydrangea petiolaris	2	0.017
Schizophragma hydrangeoides	2	0.017
Kerria japonica	2	0.017
Potentilla fragarioides var. *major*	2	0.017
Prunus nipponica	2	0.017
Sorbus gracilis	2	0.017
Sapium japonicum	2	0.017
Acer crataegifolium (leaf 1, samara 1)	2	0.017
Celastrus orbiculatus	2	0.017
Vitis coignetiae	2	0.017
Aralia cordata (leaflet 1, fruit 1)	2	0.017
Pterostyrax hispida (leaf 1, shoot with leaf and seeds 1)	2	0.017
Potamogeton perfoliatus	2	0.017
Polystichum tripteron	1	0.009
Blechnum amabile	1	0.009
Cryptomeria japonica	1	0.009
Juniperus rigida	1	0.009
Juglans ailanthifolia	1	0.009
Populus maximowiczii	1	0.009
Salix integra	1	0.009
Alnus maximowiczii	1	0.009
Betula platyphylla var. *japonica*	1	0.009

第4表　（つづき）
Table 4　(continued)

Species	Number of specimens	Per cent
Quercus aliena	1	0.009
Morus bombycis	1	0.009
Polygonum cuspidatum	1	0.009
Lindera membranacea	1	0.009
Clematis apiifolia var. *biternata*	1	0.009
Berberis amurensis var. *japonica*	1	0.009
Cardiandra alternifolia	1	0.009
Hydrangea hirta	1	0.009
Philadelphus satsumanus	1	0.009
Ribes ambiguum	1	0.009
Rodgersia podophylla	1	0.009
Aruncus sylvester	1	0.009
Prunus ssiori	1	0.009
Rubus crataegifolius	1	0.009
Rubus sp.	1	0.009
Dumasia truncata	1	0.009
Acer mono var. *marmoratum*	1	0.009
Acer palmatum	1	0.009
Acer sieboldianum (samara)	1	0.009
Acer tenuifolium	1	0.009
Aesculus turbinata	1	0.009
Vitis flexuosa	1	0.009
Styrax obassia	1	0.009
Ligustrum tschonoskii	1	0.009
Chrysanthemum sp. cf. *C. makinoi*	1	0.009
Saussurea sp.	1	0.009
Liliaceae gen. et sp. indet.	1	0.009
Sasa sp. cf. *S. kurilensis*	1	0.009
Gramineae gen. et sp. indet.	1	0.009
Total	11,494	100.0%

Note : Unless otherwise indicated, the organs recorded are leaves or leaflets.

第5表　大型化石の生活形別一覧表.

Table 5　Assumed growth habits of the Shiobara plants. (macrofossil)

Trees

Abies firma
Larix leptolepis
Picea polita
Pinus parviflora
Tsuga sieboldii
Cryptomeria japonica
Chamaecyparis pisifera
Juniperus rigida
Thuja standishii
Juglans ailanthifolia
Pterocarya rhoifolia
Populus maximowiczii
Populus sieboldii
Salix sachalinensis
Alnus firma
Alnus hirsuta var. *sibirica*
Betula davurica
Betula ermani
Betula grossa
Betula maximowicziana
Betula nikoensis
Betula platyphylla var. *japonica*
Betula schmidtii
Carpinus cordata
Carpinus japonica
Carpinus laxiflora
Carpinus tschonoskii
Castanea crenata
Fagus crenata
Fagus japonica
Quercus aliena
Quercus mongolica var. *grosseserrata*
Quercus serrata
Celtis jessoensis
Ulmus davidiana var. *japonica*
Ulmus laciniata
Cudrania tricuspidata
Morus bombycis
Magnolia obovata
Trochodendron aralioides
Trochodendron aralioides var. *longifolium*
Euptelea polyandra
Cercidiphyllum japonicum
Cercidiphyllum magnificum
Stewartia pseudo-camellia
Hamamelis japonica
Hamamelis japonica var. *obtusata*
Hamamelis megalophylla
Prunus apetala
Prunus jamasakura
Prunus maximowiczii
Prunus nipponica
Prunus sargentii
Prunus ssiori
Pyrus pyrifolia
Sorbus alnifolia
Sorbus commixta
Sorbus japonica
Cladrastis platycarpa
Gleditsia japonica
Maccckia amurensis var. *buergeri*
Sapium japonicum
Rhus trichocarpa
Acer crataegifolium
Acer diabolicum
Acer japonicum
Acer micranthum
Acer miyabei
Acer mono
Acer mono var. *glaucum*
Acer mono var. *marmoratum*
Acer nikoense
Acer palmatum
Acer palmatum var. *amoenum*

Acer rufinerve
Acer sieboldianum
Acer tenuifolium
Aesculus turbinata
Ilex macropoda
Buxus microphylla var. *japonica*
Berchemia berchemiaefolia
Tilia japonica
Cornus controversa
Cornus kousa
Acanthopanax sciadophylloides
Kalopanax septemlobus
Clethra barbinervis
Lyonia ovalifolia var. *elliptica*
Pterostyrax hispida
Styrax japonica
Styrax obassia
Fraxinus lanuginosa

Small trees or shrubs

Salix integra
Alnus maximowiczii
Alnus pendula
Corylus sieboldiana
Lindera membranacea
Lindera obtusiloba
Lindera umbellata
Parabenzoin praecox
Berberis amurensis var. *japonica*
Corylopsis gotoana
Deutzia scabra
Hydrangea hirta
Hydrangea paniculata
Philadelphus satsumanus
Ribes ambiguum
Ribes fasciculatum
Chaenomeles japonica
Crataegus maximowiczii
Kerria japonica
Malus sieboldii
Pourthiaea villosa
Rosa multiflora
Rubus crataegifolius
Rubus palmatus
Rubus sp.
Sorbus gracilis
Stephanandra incisa
Enkianthus campanulatus
Rhododendron degronianum
Rhododendron kaempferi
Rhododendron quinquefolium
Rhododendron wadanum
Tripetaleia paniculata var. *latifolia*
Ligustrum tschonoskii
Viburnum dilatatum
Viburnum furcatum
Viburnum phlebotrichum
Viburnum sieboldii
Viburnum wrightii
Sasa sp. cf. *S. kurilensis*
Sasa sp. cf. *S. palmata*

Vines

Clematis apiifolia
Clematis apiifolia var. *biternata*
Actinidia arguta
Actinidia polygama
Hydrangea petiolaris
Schizophragma hydrangeoides
Wisteria floribunda
Rhus ambigua
Celastrus orbiculatus
Berchemia racemosa
Parthenocissus tricuspidata
Vitis coignetiae
Vitis flexuosa

Terrestrial herbs

Davallia mariesii	*Aruncus sylvester*
Athyrium yokoscense	*Potentilla fragarioides* var. *major*
Polystichum tripteron	*Dumasia truncata*
Woodsia manchuriensis	*Aralia cordata*
Woodsia polystichoides	*Galium kinuta*
Blechnum amabile	*Artemisia princeps*
Boehmeria tricuspis	*Chrysanthemum* sp. cf. *C. makinoi*
Polygonum cuspidatum	*Saussurea* sp.
Cardiandra alternifolia	Liliaceae gen. et sp. indet.
Rodgersia podophylla	Gramineae gen. et sp. indet.
Saxifraga fortunei	

Aquatic herbs

Ceratophyllum demersum	*Potamogeton maackianus*
Myriophyllum spicatum	*Potamogeton perfoliatus*

japonica（イヌブナ），*Castanea crenata*（クリ），*Betula schimidtii*（オノオレカンバ），*Quercus mongolica* var. *grosseserrata*（ミズナラ）の順となっている．これら18種のうち11種が冷温帯種であるが，その中で *Lyonia ovalifolia* var. *elliptica*（ネジキ）が暖温帯種，*Castanea crenata, Clethra barbinervis*（リョウブ）など6種が冷温帯から暖温帯にかけて分布する樹種である．

一方，1%には満たないが，0.1%（12個体）以上を占める種が46種あり，その大半が冷温帯種であるが，常緑広葉樹の *Trochodendron aralioides*（ヤマグルマ）及び *Buxus microphylla* var. *japonica*（ツゲ）や落葉広葉樹の *Carpinus laxiflora*（アカシデ），*Quercus serrata*（コナラ），*Lindera obtusiloba*（ダンコウバイ），*Hamamelis japonica*（マンサク），*Pouthiaea villosa*（カマツカ），*Acer rufinerve*（ウリハダカエデ），*Viburnum sieboldii*（ゴマキ）など冷温帯から暖温帯に普通な樹種も含まれている．塩原化石植物群171種中，化石産出量が0.1%（12個体）にも満たない種が107種に及び，そのうち，わずか1個体（0.009%）しか産出しない種が38種にもなっている．

生活形別にみた塩原化石植物群は第5表に示したように，高木が92種で圧倒的に多く，全体の53.8%に達している．次いで低木41種（24.0%），陸生草本21種（12.3%）の順となっており，陸生草本類が比較的大きい比率を占めている．遠藤（1931 b）は更新世の横浜化石植物群や塩原化石植物群から陸生の双子葉に属する草本が全然見当たらないと述べるとともに，それらは更新世以後の気候変化に伴って出現したものであろうと考えた．しかし，今回のデータからはこの考えは支持されない．

第6表に示した種数と個体数の比率の差から明らかなように，高木は種数による比率では全体の53.8%であるのに標本個体数比では90.1%であって，高木は種数に比較して化石の産出量が多いことを示している．一方，陸生草本は，それとは逆に種数の割合に産出量が少なくなっている．草本類が高木類に比べて化石の産出量が少ないのは，高木類は一般に大型で葉の生産量が多い上，葉が枝から容易に分離し，堆積の場へ移動するのに有利な条件を備えているが，草本類の多くは小型である上に根や茎から葉が離脱することなく，生育の場で朽ちてしまうため化石として残りにくいことが原因と考えられる．

V.2 花粉化石

本報告で取り扱った大型化石は，主として木の葉化石園内にある高さ（層厚）約 15 m，幅約 20 m の塩原層群泥岩部の露頭の範囲から産出したものであるが，第 8 図（55 頁）に示した柱状図からも分かるように，この露頭ではほぼ全層準に大型化石が含まれている．尾上（1984）はこの露頭の上・中・下の 3 層準について予察的に花粉分析を行い，各層準ごとの特徴を示唆する結果を得た．今回は前回の花粉分析試料 3 点に新たに 10 点を加え，詳細な解析を試みた．花粉分析に用いた試料は，花粉の含有量と保存を考えて，大型化石が含まれている粘土質とシルト質の細互層からなる泥岩を選んだ．

V.2.1 処理の方法

分析の順序は下記の通りである．

試料粉砕 →20 g 秤量 →塩酸処理 →フッ化水素処理 →重液（臭化亜鉛，比重 2.9）分離 →アセトリシス処理 →苛性カリ処理 →検鏡（この段階で有機物残渣が多過ぎたので，シュルツェ処理）→苛性カリ処理 →封入 →検鏡．

花粉化石の計数に当たっては，プレパラート内での偏りを無くすために，1 枚のプレパラートの全域を網羅するように留意した．その結果は第 7 表に示したように，花粉・胞子の産出個体数は試料ごとにかなりの開きがあるものの，最低で試料 No. 2 の 236 個から，最高は試料 No. 11 の 552 個と比較的豊富に含まれており，化石の保存状態も良好であった．

V.2.2 組 成

同定された種類（花粉化石の場合，同定される分類単位が“属”・“科”などまちまちのため，この報告では花粉化石の分類群を“種類”と言う呼び方で表現する）の数は，針葉樹（AP-1）8，広葉樹（AP-2）35，シダ植物を除く草本類（NAP）4 及びシダ植物（FS）3 の合計 50 種類で，そのほか若干の所属不明の化石が含まれている（第 7 表）．

針葉樹は分析した全試料から出現した．個体数は少ないもので試料 No. 11 の 8%，最高は試料 No. 2 の 34%となっている．種類別では，T.C.T.［T＝Taxodiaceae（スギ科）；C＝Cupressaceae（ヒノキ科）；T＝Taxaceae（イチイ科）．花粉は 30 μ 前後の球形で化石の保存状態によっては T., C., T. のい

第 6 表　大型化石の生活形組成．
Table 6　Numerical composition of assumed growth habits of the Shiobara plants. (macrofossil)

	種　数 Number of species	個　体　数 Number of specimens
高　木 (Trees)	92（ 53.8%）	10,360（ 90.1%）
低　木 (Small trees or shrubs)	41（ 24.0%）	887（ 7.7%）
つ る 植 物 (Vines)	13（ 7.6%）	57（ 0.5%）
陸 生 草 本 (Terrestrial herbs)	21（ 12.3%）	65（ 0.6%）
水 生 草 本 (Aquatic herbs)	4（ 2.3%）	125（ 1.1%）
Total	171 (100.0%)	11,494 (100.0%)

第7表　塩原層群産花粉化石一覧表.

Table 7　Numerical representation of the Shiobara flora. (microfossil)

［試料番号は第8図と共通］

(Sample numbers are the same in figure 8)

化石名 Fossil ＼ 試料番号 Sample number	1	2	3	4	5	6	7	8	9	10	11	12	13
Abies	13	10	3	3	1	2	6	1	3	24	10	11	3
Tsuga	19	25	2	2	10	2	13	1	18	8	2	18	6
Picea	9	18	2	1	5	2	14	—	15	24	25	47	12
Larix	2	—	—	1	—	—	—	—	—	—	1	—	—
Pinus	6	19	2	4	11	9	6	2	7	10	2	5	5
Sciadopitys	—	1	—	—	—	—	—	—	—	—	—	1	—
Cryptomeria	5	1	11	25	1	17	13	7	8	9	2	6	14
T. C. T.	18	6	101	93	1	94	3	56	9	29	2	10	8
(AP-1 total)	(72)	(80)	(121)	(129)	(29)	(126)	(55)	(67)	(60)	(104)	(44)	(98)	(48)
Juglans	9	13	21	12	26	8	9	4	9	19	13	4	4
Pterocarya	15	1	12	8	7	10	1	5	3	13	3	7	8
Myrica	—	—	—	1	—	—	—	—	—	—	—	1	—
Salix	3	—	—	—	—	—	—	1	—	—	1	1	—
Alnus	34	58	63	61	132	61	50	61	33	67	292	155	118
Betula	6	1	5	3	6	4	5	14	3	2	4	11	6
Carpinus	30	—	—	—	—	—	—	27	—	—	—	—	18
Carpinus-Ostrya	—	5	46	44	12	34	4	—	4	30	27	15	—
Corylus	6	1	8	6	6	10	2	2	—	1	4	4	1
Castanea	—	—	1	4	—	2	1	7	—	—	—	—	1
Fagus	41	27	120	122	44	88	37	72	104	106	56	44	19
Quercus (*Lepidobalanus*)	34	10	20	17	4	34	3	12	9	6	14	6	3
Celtis-Aphananthe	14	1	14	25	3	25	—	11	1	16	3	6	3
Ulmus	6	—	18	6	—	10	—	10	—	62	—	23	9
Zelkova	7	—	12	5	—	7	—	4	—	21	—	3	15
Ulmus-Zelkova	—	9	—	—	30	—	11	—	20	—	24	—	—
Cf. Moraceae	—	—	—	—	1	—	—	—	—	—	—	—	1
Euptelea	—	—	—	—	—	—	—	—	—	—	1	—	—
Cercidiphyllum	—	—	—	—	—	—	—	—	—	—	1	—	—
Cf. *Corylopsis*	1	—	—	—	—	—	—	—	—	—	—	—	1
Prunus	1	—	—	—	—	—	—	—	—	—	—	—	—
Rhus	—	—	—	1	—	—	—	—	—	—	—	—	1
Acer	1	1	2	2	—	5	—	1	—	1	1	—	1
Ilex	—	—	—	—	—	—	2	—	—	—	—	—	1
Buxus	—	—	—	—	—	1	—	—	—	—	2	1	—
Tilia	1	2	—	1	3	2	2	—	3	1	1	—	1
Cornus	—	—	1	—	—	—	—	—	—	—	—	—	—
Araliaceae	—	—	—	—	—	—	1	—	—	—	—	—	1
Cf. *Clethra*	—	—	1	—	—	—	—	—	—	—	—	—	—
Ericaceae	—	—	—	1	—	1	—	3	—	2	11	9	20
Styrax	—	—	—	—	—	—	—	1	—	—	—	—	—
Fraxinus	11	—	3	4	—	1	—	8	—	—	1	—	2
Ligustrum	—	—	—	2	—	1	—	—	—	—	1	—	—
Lonicera	—	—	—	—	—	—	—	—	—	—	—	—	1
Vibrunum	—	—	2	1	—	—	—	—	—	—	—	1	1
(AP-2 total)	(220)	(129)	(349)	(326)	(274)	(304)	(128)	(243)	(189)	(347)	(460)	(291)	(236)
Artemisia	9	1	12	6	11	2	2	4	1	3	8	2	18
Gramineae	3	3	1	2	4	6	4	4	—	4	19	58	16
Cyperaceae	2	1	4	3	1	4	—	2	8	—	1	2	3
Other NAP	1	2	1	1	—	1	4	2	—	—	7	7	6
(NAP total)	(15)	(7)	(18)	(12)	(16)	(13)	(10)	(12)	(9)	(7)	(35)	(69)	(43)
Lycopodium	35	—	—	—	—	—	2	1	—	—	—	—	—
Polypodiaceae	—	—	—	—	—	2	—	3	—	1	—	13	5
Other Pteridophyta	83	3	6	12	5	7	59	52	8	5	8	41	23
(FS total)	(118)	(3)	(6)	(12)	(5)	(9)	(61)	(56)	(8)	(6)	(8)	(54)	(28)
Unknown	3	17	3	6	4	4	4	3	3	3	5	10	4
Total Number	428	236	497	485	328	456	258	381	269	467	552	522	359

T. C. T. (Taxodiaceae, Cupressaceae, Taxaceae)　AP-1 (Aboreal Pollen : Conifer tree)
AP-2 (Aboreal Pollen : Broad-leaved tree)　NAP (Non Aboreal Pollen)　FS (Fern Spore)

ずれか区別できない種類］が試料 Nos. 3, 4, 6 でそれぞれ 20.3, 19.2, 20.6%を占めて圧倒的に多く，*Abies*（モミ属），*Tsuga*（ツガ属），*Picea*（トウヒ属），*Pinus*（マツ属）及び *Cryptomeria*（スギ属）も比較的多く産出している．

広葉樹花粉では *Juglans*（クルミ属），*Pterocarya*（サワグルミ属），*Alnus*（ハンノキ属），*Fagus*（ブナ属），*Quercus*（*Lepidobalanus*）（コナラ属），*Celtis-Aphananthe*（エノキ属とムクノキ属の区別がつかない化石），*Ulmus*（ニレ属），*Zelkova*（ケヤキ属），*Ulmus-Zelkova*（ニレ属とケヤキ属の区別がつかない化石）などの風媒花植物が全試料から出現しており，中でも *Alnus* が最も優勢で，次いで，大型化石としても産出量の1位と2位を占め，*Fagus crenata* 及び *F. japonica* で代表される *Fagus* が全試料から豊富に産出している．一方，Rosaceae（バラ科）や Aceraceae（カエデ科）の虫媒花植物は大型化石では種類も産出量も目立って多いが，花粉化石では Rosaceae の *Prunus*（サクラ属）が試料 No. 1 から1個体のみ，Aceraceae では *Acer*（カエデ属）が試料 No. 6 で5個体検出されている外は1～2個体で，試料 Nos. 5, 7, 9, 12 からは産出がみられない．

草本類では，*Artemisia*（ヨモギ属），Gramineae（イネ科），Cyperaceae（カヤツリグサ科）が比較的多く，シダ植物では *Lycopodium*（ヒカゲノカズラ属）が試料 No. 1 から多産するのをはじめ，各試料から多数認められている．

V.3 花粉化石の樹種の推定

VI.1 の項で述べているように，大型化石の構成種と現生植物との比較から，塩原化石植物群はブナ林を主体とした現在の冷温帯下部の植生を想定することができるが，その植生を参考にして花粉化石の主な種類について樹種を推定してみる．なお，花粉化石に対応する大型化石を第8表に示した．

針葉樹の花粉化石では，Pinaceae（マツ科）に属する *Abies*（モミ属），*Tsuga*（ツガ属），*Picea*（トウヒ属），*Larix*（カラマツ属）及び *Pinus*（マツ属）が見いだせたが，それぞれその花粉化石に対応できる大型化石が1種ずつ産出することから，花粉の種を推定できる．有翼花粉で飛翔距離の長い *Abies, Picea, Pinus* などでは大型化石から推定される種以外にも，塩原化石植物群の組成と類似の生育環境にある，現在の関東地方北部の冷温帯の樹種構成から推して，*Abies homolepis*（ウラジロモミ），*A. mariesii*（アオモリトドマツ），*Picea bicolor*（イラモミ），*P. jezoensis* var. *hondoensis*（トウヒ），*Pinus densiflora*（アカマツ），*P. pumila*（ハイマツ）などが湖盆の周縁部に生育していたことも十分想定される．

Cryptomeria（スギ属）は現在1属1種であり，かつ塩原化石植物群は1種を除き日本に自生する種であることから *C. japonica*（スギ）と考えられる．一方，T.C.T. に該当する大型化石としては Taxodiaceae（スギ科）の *Cryptomeria japonica*, Cupressaceae（ヒノキ科）の *Chamaecyparis pisifera*（サワラ），*Juniperus rigida*（ネズ），*Thuja standishii*（クロベ）が産出しているが，花粉化石では，それ以外にも Taxaceae（イチイ科）の *Taxus cuspidata*（イチイ），*Torreya nucifera*（カヤ），Cupressaceae の *Chamaecyparis obtusa*（ヒノキ）及び *Thujopsis dolabrata*（アスナロ）が含まれていたものと想定される．

広葉樹の花粉化石では，Juglandaceae（クルミ科）の *Juglans*（クルミ属）及び *Pterocarya*（サワグルミ属）が大型化石の *Juglans ailanthifolia*（オニグルミ）と *Pterocarya rhoifolia*（サワグルミ）にそれぞれ相当する．現在日本の *Juglans* と *Pterocarya* はそれぞれ1属1種であるので，他の樹種が含まれている可能性はほとんどない．

Myrica（ヤマモモ属）に該当する大型化石は産出していない．大型化石の組成から推定される種としては北海道から本州中部（寒帯－冷温帯）に分布する *M. gale*（ヤチヤナギ）と，関東以西（暖温帯―亜熱帯）に分布する *M. rubra*（ヤマモモ）がある．しかし花粉化石の産出が試料 No. 4 と No. 12 からそれぞれ1個体ずつと非常に少ないことから，これらは堆積の場から離れた山地にわずかに生育していたことが考えられる．したがって，この2種のうちでは，寒帯から冷温帯に主な分布域を持つ *M. gale* の可能性が強い．

第8表　花粉化石と大型化石の比較.

Table 8　Comparative table between micro- and macrofossils.

* No occurrence

Microfossil	Macrofossil
Abies	*Abies firma*
Tsuga	*Tsuga sieboldii*
Picea	*Picea polita*
Larix	*Larix leptolepis*
Pinus	*Pinus parviflora*
Sciadopitys	*
Cryptomeria	*Cryptomeria japonica*
T.C.T.	*Chamaecyparis pisifera*
	Juniperus rigida
	Thuja standishii
Juglans	*Juglans ailanthifolia*
Pterocarya	*Pterocarya rhoifolia*
Myrica	*
*	*Populus maximowiczii*
	Populus sieboldii
Salix	*Salix integra*
	Salix sachalinensis
Alnus	*Alnus firma*
	Alnus hirsuta var. *sibirica*
	Alnus maximowiczii
	Alnus pendula
Betula	*Betula davurica*
	Betula ermani
	Betula grossa
	Betula maximowicziana
	Betula nikoensis
	Betula platyphylla var. *japonica*
	Betula schmidtii
Carpinus-Ostrya	*Carpinus cordata*
	Carpinus japonica
	Carpinus laxiflora
	Carpinus tschonoskii
Corylus	*Corylus sieboldiana*
Castanea	*Castanea crenata*
Fagus	*Fagus crenata*
	Fagus japonica

第8表　（つづき）
Table 8　(continued)

Microfossil	Macrofossil
Quercus	*Quercus aliena*
	Quercus mongolica var. *grosseserrata*
	Quercus serrata
Celtis-Aphananthe	*Celtis jessoensis*
Ulmus	*Ulmus davidiana* var. *japonica*
	Ulmus laciniata
Zelkova	*
Cf. Moraceae	*Cudrania tricuspidata*
	Morus bombycis
*	*Boehmeria tricuspis*
*	*Polygonum cuspidatum*
*	*Magnolia obovata*
*	*Lindera membranacea*
	Lindera obtusiloba
	Lindera umbellata
*	*Parabenzoin praecox*
*	*Trochodendron aralioides*
	Trochodendron aralioides var. *longifolium*
Euptelea	*Euptelea polyandra*
Cercidiphyllum	*Cercidiphyllum japonicum*
	Cercidiphyllum magnificum
*	*Clematis apiifolia*
	Clematis apiifolia var. *biternata*
*	*Berberis amurensis* var. *japonica*
*	*Ceratophyllum demersum*
*	*Actinidia arguta*
	Actinidia polygama
*	*Stewartia pseudo-camellia*
Cf. *Corylopsis*	*Corylopsis gotoana*
*	*Hamamelis japonica*
	Hamamelis japonica var. *obtusata*
	Hamamelis megalophylla
*	*Cardiandra alternifolia*
*	*Deutzia scabra*
*	*Hydrangea hirta*
	Hydrangea paniculata
	Hydrangea petiolaris

第8表　（つづき）

Table 8　(continued)

Microfossil	Macrofossil
*	*Philadelphus satsumanus*
*	*Ribes ambiguum*
	Ribes fasciculatum
*	*Rodgersia podophylla*
*	*Saxifraga fortunei*
*	*Schizophragma hydrangeoides*
*	*Aruncus sylvester*
*	*Chaenomeles japonica*
*	*Crataegus maximowiczii*
*	*Kerria japonica*
*	*Malus sieboldii*
*	*Potentilla fragarioides* var. *major*
*	*Pourthiaea villosa*
Prunus	*Prunus apetala*
	Prunus jamasakura
	Prunus maximowiczii
	Prunus nipponica
	Prunus sargentii
	Prunus ssiori
*	*Pyrus pyrifolia*
*	*Rosa multiflora*
*	*Rubus crataegifolius*
	Rubus palmatus
	Rubus sp.
*	*Sorbus alnifolia*
	Sorbus commixta
	Sorbus gracilis
	Sorbus japonica
*	*Stephanandra incisa*
*	*Cladrastis platycarpa*
*	*Dumasia truncata*
*	*Gleditsia japonica*
*	*Macckia amurensis* var. *buergeri*
*	*Wisteria floribunda*
*	*Sapium japonicum*
Rhus	*Rhus ambigua*
	Rhus trichocarpa

第8表　（つづき）
Table 8　(continued)

Microfossil	Macrofossil
Acer	*Acer crataegifolium*
	Acer diabolicum
	Acer japonicum
	Acer micranthum
	Acer miyabei
	Acer mono
	Acer mono var. *glaucum*
	Acer mono var. *marmoratum*
	Acer nikoense
	Acer palmatum
	Acer palmatum var. *amoenum*
	Acer rufinerve
	Acer sieboldianum
	Acer tenuifolium
*	*Aesculus turbinata*
Ilex	*Ilex macropoda*
*	*Celastrus orbiculatus*
Buxus	*Buxus microphylla* var. *japonica*
*	*Berchemia berchemiaefolia*
	Berchemia racemosa
*	*Parthenocissus tricuspidata*
*	*Vitis coignetiae*
	Vitis flexuosa
Tilia	*Tilia japonica*
*	*Myriophyllum spicatum*
Cornus	*Cornus controversa*
	Cornus kousa
Araliaceae	*Acanthopanax sciadophylloides*
	Aralia cordata
	Kalopanax septemlobus
Cf. *Clethra*	*Clethra barbinervis*
Ericaceae	*Enkianthus campanulatus*
	Lyonia ovalifolia var. *elliptica*
	Rhododendron degronianum
	Rhododendron kaempferi
	Rhododendron quinquefolium
	Rhododendron wadanum
	Tripetaleia paniculata var. *latifolia*

第8表　（つづき）
Table 8　(continued)

Microfossil	Macrofossil
*	*Pterostyrax hispida*
Styrax	*Styrax japonica*
	Styrax obassia
Fraxinus	*Fraxinus lanuginosa*
Ligustrum	*Ligustrum tschonoskii*
*	*Galium kinuta*
Lonicera	*
Viburnum	*Viburnum dilatatum*
	Viburnum furcatum
	Viburnum phlebotrichum
	Viburnum sieboldii
	Viburnum wrightii
Artemisia	*Artemisia princeps*
*	*Chrysanthemum* sp. cf. *C. makinoi*
*	*Saussurea* sp.
*	*Potamogeton maackianus*
	Potamogeton perfoliatus
*	Liliaceae gen. et sp. indet.
Gramineae	*Sasa* sp. cf. *S. kurilensis*
	Sasa sp. cf. *S. palmata*
	Gramineae gen. et sp. indet.
Cyperaceae	*
Lycopodium	*
Polypodiaceae	*
Other Pteridophyta	*Davallia mariesii*
	Athyrium yokoscense
	Polystichum tripteron
	Woodsia manchuriensis
	Woodsia polystichoides
	Blechnum amabile

Salix（ヤナギ属）に相当する大型化石としては *S. integra*（イヌコリヤナギ），*S. sachalinensis*（オノエヤナギ）の2種が産出しているが，それら以外に *S. bakko*（バッコヤナギ）の花粉が含まれていてもよい．

Betulaceae（カバノキ科）は大型化石では種数・産出個体数共に豊富である．第8表に示した通り，鑑定した花粉化石に対応できる大型化石は *Alnus*（ハンノキ属）4種，*Betula*（カバノキ属）7種，*Carpinus*（シデ属）4種，*Corylus*（ハシバミ属）1種となっている．花粉化石からみて更に予想される種は，*Alnus* が *A. japonica*（ハンノキ），*A. matsumurae*（ヤハズハンノキ），*A. sieboldiana*（オオバヤシャブシ），*Betula* は *B. corylifolia*（ウラジロカンバ），*B. globispica*（ジゾウカンバ）などである．

Carpinus-Ostrya は外形がほぼ球状を示し，わずかに孔口が突出しており，化石の保存状態によっては *Carpinus* と *Ostrya*（アサダ属）の区別がしにくい種類である．大型化石からは *Ostrya* に相当する化石は現在までのところ産出していない．一方，*Carpinus* は現在日本に生育するシデ属のすべて（4種）が大型化石として発見されていることから，この種類の花粉化石は *Carpinus* と考えられる．しかし，大型化石群によって推定される気候帯の現植生から判断すれば *Ostrya* が含まれていることも考えられる．

Corylus（ハシバミ属）は，現在 *C. heterophylla*（ハシバミ），*C. sieboldiana*（ツノハシバミ）及び *C. sieboldiana* var. *mandshurica*（オオツノハシバミ）の3種がほぼ日本全域の冷温帯に分布している．大型化石からは *C. sieboldiana* 1種のみが産出しているが，前述の樹種が含まれている可能性もある．

Castanea（クリ属）は現在日本では *C. crenata*（クリ）1種のみが冷温帯下部から暖温帯にかけて分布している．大型化石では *Fagus crenata*（ブナ），*Fagus japonica*（イヌブナ）に次いで多産（6.2%強）しているが，花粉化石では非常に少ない．クリは穂状花序を有し一見風媒花と間違われるが，実は花粉生産量の少ない虫媒花で，その特質がこの分析結果にもはっきり現われている．

Fagus（ブナ属）は現在日本では *F. crenata* 及び *F. japonica* の2種がある．*F. crenata* は北海道南部から九州までの冷温帯に分布し，一方，*F. japonica* は本州における太平洋側の *F. crenata* よりやや低い山地の，主として冷温帯下部に生育している．このように，両者が生育する環境がやや異なっているので，花粉分析の際に両者の識別がはっきりできるようになれば，環境解析により有効な材料となるはずであるが，現段階では両者の識別はむずかしい．大型化石では上述の2種が多産しているが，花粉化石でも *Alnus* に次いで多く，その中で試料ごとの数の増減が植生の変化を考察する上で有効な指標となっている．

Quercus（コナラ属）は主として暖温帯から亜熱帯に分布する常緑カシ類の *Cyclobalanopsis*（アカガシ亜属）と，主として冷温帯から暖温帯に生育する落葉カシ類の *Lepidobalanus*（コナラ亜属）に大別されている．花粉の大きさも前者が20～25 μ，後者が30～36 μ となっていてはっきり両者の区別ができるため（徳永，1972），考察上有用である．今回検出された花粉化石は *Lepidobalanus* である．大型化石では落葉カシ類の3種が産出しているが，常緑カシ類は発見されていない．

Celtis-Aphananthe は *Celtis*（エノキ属）と *Aphananthe*（ムクノキ属）の区別が明確でなかったもので，大きさ30～40 μ，ほぼ円形で3（時に4）個の孔がある花粉である．*Celtis* は現在日本には冷温帯から亜熱帯に分布するし，*C. sinensis*（エノキ），冷温帯の *C. jessoensis*（エゾエノキ），及び山口県・九州・小笠原・琉球の暖温帯から亜熱帯にかけて生育する *C. biondii*（コバノチョウセンエノキ）の3種があるが，大型化石としては *C. jessoensis* 1種が比較的多く産出している．一方，*Aphananthe* は *A. aspera*（ムクノキ）1種が現在は本州の関東以西から四国・九州・琉球などの暖温帯から亜熱帯にかけて分布しているが，塩原では大型化石は産出していない．したがって大型化石から類推される種は *C. jessoensis* であるが，その他の2種が含まれている可能性もある．

Ulmus（ニレ属）の日本産の現生種は *U. davidiana* var. *japonica*（ハルニレ），*U. laciniata*（オヒョウ）及び *U. parvifolia*（アキニレ）があり，大型化石では前2者が産出している．

Zelkova（ケヤキ属）は日本では *Z. serrata*（ケヤキ）1種のみで，本州・四国・九州の冷温帯下部から暖温帯に分布している．大型化石は塩原では現在までのところ1個体も発見されていない．かつて，

小泉（1940；p. 17, fig. 6）は塩原層群から *Zelkova serrata* の産出を記録しているが，今回筆者が原標本について検討したところ，葉縁が二重の細鋸歯になっていることから，*Carpinus* の1種と再同定した．しかし，花粉化石によって *Zelkova* が堆積盆地内に生育していたことが立証された．

Ulmus-Zelkova は，*Ulmus* と *Zelkova* の区別が明確でない花粉化石である．徳永（1972）によれば，*Ulmus* は花粉粒の大きさが22～40 μ で，外形はほぼ球形をしている．一方，*Zelkova* は30～40 μ で，全体としてやや角ばった球形で，表面のしわが *Ulmus* より粗い点で区別できるとしている．しかし，化石の保存状態によっては *Ulmus* と *Zelkova* の区別ができないものもある．

Euptelea（フサザクラ属）では現在日本に *E. polyandra*（フサザクラ）1種のみが本州及び九州の冷温帯から暖温帯に分布しており，大型化石からも葉と果実が産出している．

Cercidiphyllum（カツラ属）は大型化石では *C. japonicum*（カツラ）と *C. magnificum*（ヒロハカツラ）の2種が産し，特に前者は多産している．花粉化石では試料 No. 11 からわずか1個体が検出されたに過ぎない．

Prunus（サクラ属）を含む Rosaceae（バラ科）は大型化石では最も多くの種を有する科であるが，花粉化石では *Prunus* 1属で，しかも1個体しか検出されていない．

Acer（カエデ属）は大型化石として14種が産出し，個体数においても比較的豊富である．現在の冷温帯に生育する *Acer* は約30種に及んでいるが，花粉化石としては出現率が非常に少ない．

Tilia（シナノキ属）は，現在日本では *T. kiusiana*（ヘラノキ）が暖温帯上部に，*T. japonica*（シナノキ）及び *T. maximowicziana*（オオバボダイジュ）が冷温帯に広く分布しており，大型化石では *T. japonica* が比較的多く産出している．花粉化石は産出量が少ないが，*T. japonica* 以外の種も含まれている可能性がある．

Ericaceae（ツツジ科）は，ブナ林の低木層として現在の冷温帯にはおおよそ30種が分布している．大型化石では7種産出しているが，花粉化石にはそれ以外にも *Rhododendron japonicum*（レンゲツツジ），*R. pentaphyllum* var. *nikoense*（アカヤシオ），*Vaccinium oldhami*（ナツハゼ）など多くの種が含まれている可能性がある．

Fraxinus（トネリコ属）は，大型化石としては *F. lanuginosa*（アオダモ）1種が産している．現在の冷温帯にはおよそ8種類が生育しており，すべての種が花粉化石としても産出している可能性がある．特に，ブナ林の分布域にほぼ一致して広い分布を示す *F. spaethiana*（シオジ）が含まれていることは十分想定できる．

Artemisia（ヨモギ属）はキク科に属し，主として草本類からなる風媒花植物で，花粉分析ではよく見いだされる種類である．*Artemisia* は現在の日本では寒帯から亜熱帯にかけて30種が生育しており，そのうち，冷温帯下部の山地に生育可能なものは *A. manshurica*（オトコヨモギ），*A. keiskeana*（イヌヨモギ），*A. monophylla*（ヒトツバヨモギ），*A. montana*（オオヨモギ），*A. princeps*（ヨモギ）などがあるが，大型化石としては *A. princeps* の葉が3点産しているにすぎない．花粉化石は豊富に産しており，上記の種の存在が考えられる．

Cyperaceae（カヤツリグサ科）の多くは多年生の草本類で風媒花植物である．一般に大型化石として産することは非常にまれであるが，花粉化石としては比較的多く産出する．塩原層群においても同様に大型化石は現在までのところ発見されていない．日本の同科に属する現生種は300以上もある．花粉化石には，水際に生育する *Cyperus*（カヤツリグサ属），*Scirpus*（ホタルイ属）や，湿地から亜高山の荒れ地まで広い範囲に分布する *Carex*（スゲ属）などの花粉が多く含まれている可能性がある．

シダ植物の *Lycopodium*（ヒカゲノカズラ属）及び Polypodiaceae（ウラボシ科）が花粉化石で検出されているが大型化石は産出しない．他のシダ類は花粉化石で多産するが大型化石ではわずか6種が産出するのみである．現在日本に自生しているシダ類は400種あるいは500種とも言われており，分布する範囲も亜寒帯から亜熱帯まで広域にわたる属が多い．したがって，シダ植物の内容だけから生育環境を判定することは困難である．

V.4 大型化石と花粉化石の産出傾向

植物化石の研究においては，化石の量的な産出傾向がそのままその堆積層の形成された当時の植物相を反映すると速断することはできない．一般的概念としては，化石の産出量の多い植物が堆積地に近い地域に繁茂していたと解釈してよいが，植物には種ごとに葉や花粉の生産量に差があるのが普通である．前述のように，草本類は生育地で朽ちてしまう種類が多いため化石として残りにくく，堆積の場への移動が比較的容易な樹木の葉の化石が多く産出する傾向がある．

風媒花植物が虫媒花植物に比べて花粉の生産量が多いと言われているし（徳永，1972），風媒花花粉は移動も容易であるため，花粉化石植物群中では風媒花植物の花粉化石が虫媒花植物より多産する傾向がみられる．

また，大型化石は堆積盆周辺の植生を，花粉化石はさらに広い範囲の植生を代表するものと言われてきた．その理由としては，両者の移動可能距離から想定されたものである．しかし，尾上（1971）や今回の大型化石と花粉化石による研究結果によれば，この説は風媒花植物についてだけ言えるもので，虫媒花植物については当てはまらない．

宮崎県の更新世えびの化石植物群（尾上，1971）においても，大型化石と花粉化石の産出傾向を比較すると，虫媒花植物では大型化石が多く産しているにもかかわらず，花粉化石は産出していないか，少数の産出にとどまると言う傾向が示されている．したがって，花粉分析による解析では風媒花植物が主体となることは自明であり，近年盛んに行われている各地の花粉分析の結果にもこの傾向はよく現われている．

塩原層群の花粉化石も風媒花植物が圧倒的に多く，虫媒花植物が，大型化石で豊富に産していることとは対照的に僅少である．一方，大型化石では前項で述べたように，高木に相当する樹種の化石産出量が多く，草本類は種数の割合に産出量は非常に少ない．

塩原化石植物群を大型化石と花粉化石の産出傾向から次に示すような区分ができる．

1) 花粉化石のみ産出する植物
2) 花粉化石の産出量が優勢な植物
3) 花粉化石及び大型化石がともに多産する植物
4) 大型化石の産出量が優勢な植物
5) 大型化石のみ産出する植物

1)の花粉化石のみ産出する植物は，針葉樹の *Sciadopitys*（コウヤマキ属），広葉樹の *Myrica*（ヤマモモ属），*Zelkova*（ケヤキ属），*Lonicera*（スイカズラ属），草本類の Cyperaceae（カヤツリグサ科），*Lycopodium*（ヒカゲノカズラ属），Polypodiaceae（ウラボシ科）の7種類である．このうち，*Sciadopitys*, *Myrica* 及び *Zelkova* は風媒花植物であるが，*Sciadopitys* 及び *Myrica* は化石の産出量が少ないことから，堆積の場から離れた堆積盆地周縁部にわずかに生育していたものから花粉だけが飛来し，堆積したものである．

Zelkova は高木でしかも冷温帯下部から暖温帯に生育する樹種である．今回の調査では花粉化石の産出量が比較的多いという事実から，大型化石としても当然含まれていてよいはずの樹種であるが，これまでに大型化石は見いだされていない．この理由はまだ分からない．

Lonicera は虫媒花植物で，一般論としては虫媒花が花粉化石としては残りにくいことが指摘されているのに，今回の調査では，大型化石として産出がなく，花粉化石のみが検出されていて，通常の傾向とは反対の現象がみられる．しかし，今回産出をみたのは，わずかに花粉化石1個体にすぎないので，これらから確度の高い推論を試みることはできない．ただ，出現頻度からみて，盆地内にこの種が生育していたものの，個体数は少なかったと考えられる．

上記の草本類が花粉化石のみからなるのは大型化石として残りにくい性質が原因と考えられる．

2)の花粉化石の産出量が優勢な植物の主なものは，*Larix*（カラマツ属）と *Sciadopitys* を除く針葉樹，*Artemisia*（ヨモギ属）及び Gramineae（イネ科）があげられる．これらはいずれも風媒花植物で，大型化石の産出が少ないことから考えると，針葉樹については堆積の場から離れて分布していたものと

思われる．特に草本類の Gramineae については湖畔の湿地に生育する現生種が多いことから，生育の場で朽ちてしまって葉が残りにくかったものと推測される．

3)の花粉・大型両化石とも多産する植物は，*Alnus*（ハンノキ属），*Betula*（カバノキ属），*Carpinus*（シデ属），*Fagus*（ブナ属），*Quercus*（*Lepidobalanus*)(コナラ亜属），*Celtis*（エノキ属）及び *Ulmus*（ニレ属）のいずれも風媒花植物で，これらは堆積地周辺に繁茂していたことを示している．

4)の大型化石の産出量が優勢な植物はその種類が多い．そのなかで特に大型化石と花粉化石で産出量に大きな開きのあるものは *Castanea*（クリ属），*Cercidiphyllum*（カツラ属），*Prunus*（サクラ属），*Acer*（カエデ属），*Cornus*（ミズキ属），*Clethra*（リョウブ属）及び *Vibrunum*（ガマズミ属）で，これらの大部分は虫媒花植物である．大型化石の産出量から推定して，分布域は塩原化石湖周辺にあって，しかも比較的広い範囲で繁茂していたことは確かである．

5)の大型化石のみ産出する植物は，第8表で明らかなように，51属・70種に及んでいる．大型化石の産出量は様々であるが，4)と同様に花粉化石が含まれていない主な原因はこれらが虫媒花植物であるためと推測される．

VI. 大型化石と花粉化石からみた植物相

VI.1 現生植物との比較

塩原化石植物群を構成している171種のうち，“種”まで同定できないために，その森林分布帯が明確でない4種を除いた167種を主な検討材料とした．167種はいずれも現生種であり，朝鮮半島南部，中国にのみ自生する1種を除いたほかはすべて現在の日本に自生していることから，塩原化石植物群が示す古環境を解明するための資料は現生種の特徴から得ることができる．

かつて，遠藤（1931 a)は塩原化石植物群に絶滅種が10%含まれているとしたが，それらの標本を検討した結果，いずれの化石種も現生種の葉形変化内に納まることが明らかとなった．

第9，10表は，塩原層群堆積当時の環境を復元するために，化石植物群の構成種の現在の分布範囲を示したものである．各植物種の分布範囲は，主として北村・村田（1972，1981，1982），北村・村田・堀（1972）及び北村・村田・小山（1971）によった．また，各気候帯と森林帯などとの関係については第11表に示した．

第9表で明らかなように，塩原化石植物群は167種中166種までが現在の日本の北海道から琉球までのいずれかの地域に分布し，しかもその大部分は化石産地のある関東地方北部に生育している．一方，塩原化石植物群に含まれていて，関東地方北部に現在は生育していないものは，*Crataegus maximowiczii*（オオバサンザシ)(北海道），*Acer mono* var. *glaucum*（ウラジロイタヤ)(東北），*Clematis apiifolia* var. *biternata*（コボタンズル)(中部），*Corylopsis gotoana*（ミヤマトサミズキ)(中部—九州），*Rubus palmatus*（ナガバモミジイチゴ)(近畿—九州），*Gleditsia japonica*（サイカチ)(中部—九州），*Viburnum sieboldii*（ゴマキ)(関東南部—九州）及び *Cudrania tricuspidata*（ハリグワ)(朝鮮半島南部，中国中—南部）の8種である．これら8種のうち，関東地方北部より北に分布する *Crataegus maximowiczii* と *Acer mono* var. *glaucum* は冷温帯に，関東地方南部以西に分布する *Clematis apiifolia* var. *biternata*, *Corylopsis gotoana*, *Rubus palmatus*, *Gleditsia japonica* 及び *Viburnum sieboldii* は冷温帯—暖温帯域に分布しており，いずれも関東北部の気候下においても生育が可能であると考えられる．残る *Cudrania tricuspidata* は現在朝鮮半島南部，済州島，中国中部～南部の暖温帯に生育している．

Cudrania tricuspidata の化石は，最近，明石市西八木海岸に分布する西八木層（更新世後期）から材化石が発見されており（鈴木・能代，1986），塩原以外にも国内で生育していたことが明らかとなった．

なお，*Tilia japonica*（シナノキ）に同定した化石の中には，現在は中国中部に自生する *Tilia miqueliana*（ボダイジュ）に葉形がよく似たものが比較的多く産している．しかし，それらは *Tilia*

第9表　塩原層群産大型化石種に相当する現生植物種の地域分布.

Table 9　Present-day distribution of the Shiobara species. (macrofossil)

Shiobara species \ Region	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Davallia mariesii			×	×	×	×	×	×	×	×	×		×	×
Athyrium yokoscense	×	×	×	×	×	×	×	×	×	×	×		×	×
Polystichum tripteron	×	×	×	×	×	×	×	×	×	×	×		×	×
Woodsia manchuriensis	×	×	×	×	×	×	×	×	×	×	×			
Woodsia polystichoides	×	×	×	×	×	×	×	×	×	×	×		×	×
Blechnum amabile			×	×	×	×	×	×	×	×	×			
Abies firma				×	×	×	×	×	×	×	×			
Larix leptolepis					×	×	×							
Picea polita					×	×	×	×	×	×	×			
Pinus parviflora				×	×	×	×	×	×	×	×			
Tsuga sieboldii				×	×	×	×	×	×	×	×			
Cryptomeria japonica			×	×	×	×	×	×	×	×	×			
Chamaecyparis pisifera			×	×	×	×	×	×	×	×	×			
Juniperus rigida			×	×	×	×	×	×	×	×	×		×	×
Thuja standishii			×	×	×	×	×	×	×	×				
Juglans ailanthifolia	×	×	×	×	×	×	×	×	×	×	×			
Pterocarya rhoifolia	×	×	×	×	×	×	×	×	×	×	×			
Populus maximowiczii	×	×	×	×	×	×	×	×	×				×	×
Populus sieboldii	×	×	×	×	×	×	×	×	×	×	×			
Salix integra	×	×	×	×	×	×	×	×	×	×	×		×	
Salix sachalinensis	×	×	×	×	×	×	×	×	×	×				
Alnus firma				×	×	×	×	×		×	×			
Alnus hirsuta var. *sibirica*	×	×	×	×	×	×	×	×	×	×	×		×	×
Alnus maximowiczii	×	×	×	×	×	×	×	×	×				×	
Alnus pendula	×	×	×	×	×	×	×	×	×	×				
Betula davurica	×	×	×	×	×	×	×						×	×
Betula ermani	×	×	×	×	×	×	×	×		×			×	
Betula grossa			×	×	×	×	×	×	×	×	×			
Betula maximowicziana	×	×	×	×	×	×	×							
Betula nikoensis					×	×								
Betula platyphylla var. *japonica*	×	×	×	×	×	×	×							
Betula schmidtii			×	×	×	×	×						×	×
Carpinus cordata	×	×	×	×	×	×	×	×	×	×	×		×	×
Carpinus japonica			×	×	×	×	×	×	×	×	×			
Carpinus laxiflora	×	×	×	×	×	×	×	×	×	×	×		×	×

第9表　（つづき）
Table 9　(continued)

Shiobara species \ Region	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Carpinus tschonoskii			×	×	×	×	×	×	×	×	×		×	×
Corylus sieboldiana	×	×	×	×	×	×	×	×	×	×	×		×	
Castanea crenata		×	×	×	×	×	×	×	×	×	×		×	
Fagus crenata		×	×	×	×	×	×	×	×	×	×			
Fagus japonica			×	×	×	×	×	×	×	×	×			
Quercus aliena			×	×	×	×	×	×	×	×	×		×	×
Quercus mongolica var. *grosseserrata*	×	×	×	×	×	×	×	×	×	×	×			
Quercus serrata		×	×	×	×	×	×	×	×	×	×		×	
Celtis jessoensis	×	×	×	×	×	×	×	×	×	×	×		×	
Ulmus davidiana var. *japonica*	×	×	×	×	×	×	×	×	×	×	×		×	×
Ulmus laciniata	×	×	×	×	×	×	×	×	×	×	×		×	×
Cudrania tricuspidata													×	×
Morus bombycis	×	×	×	×	×	×	×	×	×	×	×		×	×
Boehmeria tricuspis	×	×	×	×	×	×	×	×	×	×	×			
Polygonum cuspidatum	×	×	×	×	×	×	×	×	×	×	×		×	×
Magnolia obovata	×	×	×	×	×	×	×	×	×	×	×			×
Lindera membranacea	×	×	×	×	×	×	×							
Lindera obtusiloba					×	×	×	×	×	×	×		×	×
Lindera umbellata			×	×	×	×	×	×	×	×	×			
Parabenzoin praecox			×	×	×	×	×	×	×	×	×			
Trochodendron aralioides			×	×	×	×	×	×	×	×	×		×	×
Trochodendron aralioides var. *longifolium*			×	×	×	×	×	×	×	×	×		×	×
Euptelea polyandra			×	×	×	×	×	×	×	×	×			
Cercidiphyllum japonicum	×	×	×	×	×	×	×	×	×	×	×			
Cercidiphyllum magnificum			×	×	×	×	×							
Clematis apiifolia			×	×	×	×	×	×	×	×	×		×	×
Clematis apiifolia var. *biternata*							×							
Berberis amurensis var. *japonica*	×	×	×	×	×	×	×	×	×	×	×		×	×
Ceratophyllum demersum	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Actinidia arguta	×	×	×	×	×	×	×	×	×	×	×		×	×
Actinidia polygama	×	×	×	×	×	×	×	×	×	×	×		×	×
Stewartia pseudo-camellia				×	×	×	×	×	×	×	×		×	
Corylopsis gotoana							×	×	×	×	×			
Hamamelis japonica			×	×	×	×	×	×	×	×	×			
Hamamelis japonica var. *obtusata*		×	×	×	×	×	×	×	×					

第9表　（つづき）
Table 9　(continued)

Shiobara species \ Region	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Hamamelis megalophylla			×	×	×	×	×							
Cardiandra alternifolia					×	×	×	×	×	×	×			
Deutzia scabra	×	×	×	×	×	×	×	×	×	×	×	×		×
Hydrangea hirta					×	×	×	×	×	×	×			
Hydrangea paniculata	×	×	×	×	×	×	×	×	×	×	×			×
Hydrangea petiolaris	×	×	×	×	×	×	×	×	×	×	×		×	
Philadelphus satsumanus				×	×	×	×	×	×	×	×			
Ribes ambiguum			×	×	×	×	×	×	×	×	×			×
Ribes fasciculatum			×	×	×	×	×	×	×	×	×		×	×
Rodgersia podophylla	×	×	×	×	×	×	×	×	×				×	
Saxifraga fortunei	×	×	×	×	×	×	×	×	×	×	×		×	×
Schizophragma hydrangeoides	×	×	×	×	×	×	×	×	×	×	×			
Aruncus sylvester	×	×	×	×	×	×	×	×	×	×	×		×	×
Chaenomeles japonica			×	×	×	×	×	×	×	×	×			
Crataegus maximowiczii	×	×											×	×
Kerria japonica	×	×	×	×	×	×	×	×	×	×	×			×
Malus sieboldii	×	×	×	×	×	×	×	×	×	×	×		×	
Potentilla fragarioides var. *major*	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Pourthiaea villosa			×	×	×	×	×	×	×	×	×		×	×
Prunus apetala			×	×	×	×	×	×	×	×	×			
Prunus jamasakura					×	×	×	×	×	×	×		×	
Prunus maximowiczii	×	×	×	×	×	×	×	×	×	×	×		×	×
Prunus nipponica	×	×	×	×	×	×	×							
Prunus sargentii	×	×	×	×	×	×	×						×	
Prunus ssiori	×	×	×	×	×	×	×							
Pyrus pyrifolia			×	×	×	×	×	×	×	×	×		×	×
Rosa multiflora	×	×	×	×	×	×	×	×	×	×	×		×	
Rubus crataegifolius	×	×	×	×	×	×	×	×	×	×	×		×	×
Rubus palmatus								×	×	×	×		×	×
Sorbus alnifolia	×	×	×	×	×	×	×	×	×	×	×		×	×
Sorbus commixta	×	×	×	×	×	×	×	×	×	×	×		×	×
Sorbus gracilis					×	×	×	×	×	×	×			
Sorbus japonica			×	×	×	×	×	×	×	×	×			
Stephanandra incisa	×	×	×	×	×	×	×	×	×	×	×		×	×
Cladrastis platycarpa				×	×	×	×	×	×					

第9表　（つづき）
Table 9　(continued)

Region / Shiobara species	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Dumasia truncata			×	×	×	×	×	×	×	×	×			
Gleditsia japonica							×	×	×	×	×			
Macckia amurensis var. *buergeri*	×	×	×	×	×	×	×						×	×
Wisteria floribunda			×	×	×	×	×	×	×	×	×			
Sapium japonicum			×	×	×	×	×	×	×	×	×	×	×	×
Rhus ambigua	×	×	×	×	×	×	×	×	×	×	×	×		×
Rhus trichocarpa	×	×	×	×	×	×	×	×	×	×	×		×	×
Acer crataegifolium				×	×	×	×	×	×	×	×			
Acer diabolicum			×	×	×	×	×	×	×	×	×			
Acer japonicum	×	×	×	×	×	×	×	×	×					
Acer micranthum	×	×	×	×	×	×	×	×	×	×	×			
Acer miyabei	×	×	×	×	×	×	×							
Acer mono		×	×	×	×	×	×	×	×	×	×			
Acer mono var. *glaucum*			×	×										
Acer mono var. *marmoratum*			×	×	×	×	×	×	×	×	×			
Acer nikoense			×	×	×	×	×	×	×	×	×			
Acer palmatum				×	×	×	×	×	×	×	×		×	×
Acer palmatum var. *amoenum*	×	×	×	×	×	×	×	×	×	×				
Acer rufinerve			×	×	×	×	×	×	×	×	×			
Acer sieboldianum	×	×	×	×	×	×	×	×	×	×	×			
Acer tenuifolium					×	×	×	×	×	×	×			
Aesculus turbinata	×	×	×	×	×	×	×	×	×	×	×			
Ilex macropoda	×	×	×	×	×	×	×	×	×	×	×		×	×
Celastrus orbiculatus			×	×	×	×	×	×	×	×	×		×	×
Buxus microphylla var. *japonica*					×	×	×	×	×	×	×			
Berchemia berchemiaefolia			×	×	×	×	×	×	×	×	×			
Berchemia racemosa	×	×	×	×	×	×	×	×	×	×	×	×		
Parthenocissus tricuspidata	×	×	×	×	×	×	×	×	×	×	×		×	×
Vitis coignetiae	×	×	×	×	×	×	×	×	×	×				
Vitis flexuosa			×	×	×	×	×	×	×	×	×		×	×
Tilia japonica	×	×	×	×	×	×	×	×	×	×	×			
Myriophyllum spicatum	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Cornus controversa	×	×	×	×	×	×	×	×	×	×	×		×	×
Cornus kousa			×	×	×	×	×	×	×	×	×		×	
Acanthopanax sciadophylloides	×	×	×	×	×	×	×	×	×	×	×			

第9表　（つづき）
Table 9　(continued)

Region / Shiobara species	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Aralia cordata	×	×	×	×	×	×	×	×	×	×	×		×	×
Kalopanax septemlobus	×	×	×	×	×	×	×	×	×	×	×		×	×
Clethra barbinervis		×	×	×	×	×	×	×	×	×	×		×	
Enkianthus campanulatus		×	×	×	×	×	×	×	×					
Lyonia ovalifolia var. *elliptica*				×	×	×	×	×	×	×	×			
Rhododendron degronianum				×	×	×	×							
Rhododendron kaempferi	×	×	×	×	×	×	×	×	×	×	×			
Rhododendron quinquefolium			×	×	×	×	×	×		×				
Rhododendron wadanum				×	×	×	×	×						
Tripetaleia paniculata var. *latifolia*		×	×	×	×	×	×	×	×	×	×			
Pterostyrax hispida			×	×	×	×	×	×	×	×	×			
Styrax japonica	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Styrax obassia	×	×	×	×	×	×	×	×	×	×	×		×	×
Fraxinus lanuginosa	×	×	×	×	×	×	×	×	×	×	×		×	
Ligustrum tschonoskii	×	×	×	×	×	×	×	×	×	×	×			
Galium kinuta			×	×	×	×	×	×	×	×	×			
Viburnum dilatatum	×	×	×	×	×	×	×	×	×	×	×		×	×
Viburnum furcatum	×	×	×	×	×	×	×	×	×	×	×			
Viburnum phlebotrichum			×	×	×	×	×	×	×	×	×			
Viburnum sieboldii	×					×	×	×	×	×	×			
Viburnum wrightii	×	×	×	×	×	×	×	×	×	×	×		×	×
Artemisia princeps			×	×	×	×	×	×	×	×	×		×	
Chrysanthemum sp. cf. *C. makinoi*				×	×	×	×	×	×	×	×			
Potamogeton maackianus	×	×	×	×	×	×	×	×	×	×	×		×	×
Potamogeton perfoliatus	×	×	×	×	×	×	×	×	×	×	×		×	×
Sasa sp. cf. *S. kurilensis*	×	×	×	×	×	×	×	×	×					
Sasa sp. cf. *S. palmata*	×	×	×	×	×	×	×	×	×		×			
167 species	85	93	137	150	159	160	162	148	143	138	132	8	75	63

A : Northeastern Hoakkido, B : Southwestern Hokkaido, C : Northern Tohoku district, D : Southern Tohoku distrrict, E : Northern Kanto district, F : Southern Kanto district, G : Chubu district, H : Kinki district, I : Chugoku district, J : Shikoku, K : Kyushu, L : Loochoo Islands, M : Korea, N : China

japonica の葉形変異の範囲内におさまるもので，ここでは *Tilia japonica* として扱った．

第10表で，塩原化石植物群を構成している樹種の現在の垂直分布域を見ると，種まで同定できた167種のうち150種が冷温帯下部に分布域をもち，以下，冷温帯上部136種，暖温帯上部87種，暖温帯下部81種，亜熱帯7種，亜寒帯5種の順となっている．この結果からは最も多くの種が属している分布域は冷温帯下部であって，かつ，この分布域を中心に，より寒帯的な要素とより暖帯的要素が種の数としてはほぼ均等ながら，やや後者に寄った分布をしていることが読み取れる．すなわち，塩原化石植物群を構成している樹種の分布域は主として冷温帯下部にあったと言うことができる．

遠藤（1931 a）は，化石堆積時の湖盆周辺の植生が現在の中禅寺湖畔の標高1,500 m付近の植生とほぼ同じであったとしたが，その説に従うと，湖盆周辺は冷温帯上部の植物分布域となる．しかし，塩原化石植物群には冷温帯下部以下に限られて分布する植物が31種，個体数にして1,181個（16%）含まれており，次に述べるように遠藤の見解に基づけばこれらは塩原化石湖に堆積することが困難なはずである．

水流による植物遺骸の運搬を考慮に入れれば，一般に，亜高山帯（亜寒帯）や山地帯（冷温帯）などの高所に生育している植物が，その生育地より低い場所に堆積することは比較的容易であり，亜寒帯の樹木が冷温帯下部にある湖に堆積することは自然である．一方，低地帯（暖温帯）に生育していた植物が，その生育地より高い冷温帯上部の湖に堆積することは考えにくい．

今回の研究で明らかになったように，塩原化石植物群の主体が冷温帯下部にあることから，同帯下底に堆積湖盆があったと仮定した場合，157種は堆積しうるが，暖温帯以下に固有分布をする10種については見掛け上は湖に堆積できないことになる．塩原化石湖の湖面のレベルを暖温帯上部内に下げてはじめて167種全部が堆積できることになる．しかし，仮に暖温帯上部に湖面があったとすると，化石植物群の中に常緑カシ類など暖温帯種が多く含まれてこなければならず，塩原化石植物群の構成種からみて，湖面を暖温帯レベルまで下げることは考えられない．したがって，塩原化石植物群中の暖温帯種10種，産出化石の個体数の割合にして2.58%程度のものは不安定ながら冷温帯下部の植生に混在していたと解釈する方が，湖面を暖温帯上部まで下げるよりは無理がない．

現在の関東地方北部から奥羽地方には，*Fagus japonica, Carpinus*（シデ属）の仲間，*Castanea crenata, Quercus*（コナラ属）の落葉広葉樹，*Zelkova serrata*（ケヤキ）など冷温帯下部や暖温帯に普通な落葉広葉樹を主体とし，暖温帯のカシ類［*Quercus* の常緑広葉樹（*Cyclobalanopsis*)］と冷温帯の *Fagus crenata* を欠く森林帯が分布している．この特徴を示す森林帯を“中間温帯林”と呼び（鈴木時夫，1961；倉田，1970；山中，1979），冷温帯下部と暖温帯上部をつなぐ推移帯とする考え方がある（第11表）．

塩原化石植物群は *Fagus crenata* を多産するほか，冷温帯に広い分布を示す樹種も多く含まれている点でその組成は上記の中間温帯林のそれとは異なっているが，冷温帯下部を主な分布域とする *Fagus japonica* や，冷温帯下部から暖温帯にかけて分布する *Castanea crenata, Carpinus* の各種，*Quercus*（コナラ属）のうちの落葉広葉樹（*Lepidobalanus*）や，花粉化石から類推される *Zelkova serrata* など中間温帯林に豊富な種も多く含まれていることから，同化石植物群は冷温帯下部の中間温帯林の分布域と近接した環境下に生育していたものと推定できる．このような観点からも塩原化石植物群は，冷温帯上部とする遠藤の考えを修正する必要がある．

塩原盆地周辺の現在の植生は，大半が表日本型のブナ林で特徴づけられ，一部裏日本型のブナ林が存在していることはIII.3植生の項で述べたが，塩原層群堆積当時においても，ほぼ同じ傾向にあったことが化石植物群の内容から読み取ることができる．すなわち，塩原化石植物群は *Alnus firma*（ヤシャブシ），*Fagus japonica, Hamamelis japonica*（マンサク），*Rhododendron quinquefolium*（ゴヨウツツジ）など表日本固有の樹種が多産するほか，大部分が表日本に優勢な樹種で占められている．そのなかにあって，*Alnus pendula*（ヒメヤシャブシ），*Lindera membranacea*（オオバクロモジ），*Hamamelis japonica* subsp. *obtusata*（マルバマンサク），*Sasa* sp. cf. *S. kurilensis*（チシマザサ）及び *Sasa* sp. cf. *S. palmata*（チマキザサ）などの裏日本固有種が少数ながら含まれている．また，日本の冷温帯に広く分

第10表　塩原層群産大型化石種に相当する現生植物種の気候帯中での分布.

Table 10　Present-day distribution of the Shiobara species on the climatic zone in Japan. (macrofossil)

(The figures in parentheses are number of specimens)

Shiobara species \ Climatic zone	Sub-arctic	Cool temperate		Warm temperate		Sub-tropic
		Up.	Low.	Up.	Low.	
Davallia mariesii (11)						
Athyrium yokoscense (4)						
Polystichum tripteron (1)						
Woodsia manchuriensis (8)						
Woodsia polystichoides (15)						
Blechnum amabile (1)						
Abies firma (3)						
Larix leptolepis (6)						
Picea polita (23)						
Pinus parviflora (12)						
Tsuga sieboldii (22)						
Cryptomeria japonica (1)						
Chamaecyparis pisifera (2)						
Juniperus rigida (1)						
Thuja standishii (45)						
Juglans ailanthifolia (1)						
Pterocarya rhoifolia (36)						
Populus maximowiczii (1)						
Populus sieboldii (4)						
Salix integra (1)						
Salix sachalinensis (5)						
Alnus firma (523)						
Alnus hirsuta var. *sibirica* (80)						
Alnus maximowiczii (1)						
Alnus pendula (8)						
Betula davurica (5)						
Betula ermani (2)						
Betula grossa (605)						
Betula maximowicziana (15)						
Betula nikoensis (5)						
Betula platyphylla var. *japonica* (1)						
Betula schmidtii (650)						
Carpinus cordata (53)						
Carpinus japonica (121)						

第10表　（つづき）
Table 10　(continued)

Climatic zone / Shiobara species	Sub-arctic	Cool temperate		Warm temperate		Sub-tropic
		Up.	Low.	Up.	Low.	
Carpinus laxiflora (18)						
Carpinus tschonoskii (3)						
Corylus sieboldiana (14)						
Castanea crenata (718)						
Fagus crenata (1,528)						
Fagus japonica (1,294)						
Quercus aliena (1)						
Quercus mongolica var. *grosseserrata* (607)						
Quercus serrata (31)						
Celtis jessoensis (35)						
Ulmus davidiana var. *japonica* (155)						
Ulmus laciniata (3)						
Cudrania tricuspidata (4)						
Morus bombycis (1)						
Boehmeria tricuspis (2)						
Polygonum cuspidatum (1)						
Magnolia obovata (70)						
Lindera membranacea (1)						
Lindera obtusiloba (35)						
Lindera umbellata (3)						
Parabenzoin praecox (5)						
Trochodendron aralioides (88)						
Trochodendron aralioides var. *longifolium* (5)						
Euptelea polyandra (4)						
Cercidiphyllum japonicum (400)						
Cercidiphyllum magnificum (2)						
Clematis apiifolia (3)						
Clematis apiifolia var. *biternata* (1)						
Berberis amurensis var. *japonica* (1)						
Ceratophyllum demersum (45)						
Actinidia arguta (18)						
Actinidia polygama (3)						
Stewartia pseudo-camellia (412)						
Corylopsis gotoana (18)						

第10表　（つづき）
Table 10　(continued)

Shiobara species \ Climatic zone	Sub-arctic	Cool temperate		Warm temperate		Sub-tropic
		Up.	Low.	Up.	Low.	
Hamamelis japonica (87)						
Hamamelis japonica var. *obtusata* (3)						
Hamamelis megalophylla (4)						
Cardiandra alternifolia (1)						
Deutzia scabra (2)						
Hydrangea hirta (1)						
Hydrangea paniculata (78)						
Hydrangea petiolaris (2)						
Philadelphus satsumanus (1)						
Ribes ambiguum (1)						
Ribes fasciculatum (3)						
Rodgersia podophylla (1)						
Saxifraga fortunei (3)						
Schizophragma hydrangeoides (2)						
Aruncus sylvester (1)						
Chaenomeles japonica (3)						
Crataegus maximowiczii (4)						
Kerria japonica (2)						
Malus sieboldii (3)						
Potentilla fragarioides var. *major* (2)						
Pourthiaea villosa (85)						
Prunus apetala (3)						
Prunus jamasakura (18)						
Prunus maximowiczii (3)						
Prunus nipponica (2)						
Prunus sargentii (3)						
Prunus ssiori (1)						
Pyrus pyrifolia (4)						
Rosa multiflora (8)						
Rubus crataegifolius (1)						
Rubus palmatus (3)						
Sorbus alnifolia (288)						
Sorbus commixta (84)						
Sorbus gracilis (2)						

第10表　（つづき）
Table 10　(continued)

Shiobara species \ Climatic zone	Sub-arctic	Cool temperate		Warm temperate		Sub-tropic
		Up.	Low.	Up.	Low.	
Sorbus japonica (32)						
Stephanandra incisa (6)						
Cladrastis platycarpa (5)						
Dumasia truncata (1)						
Gleditsia japonica (11)						
Maccckia amurensis var. *buergeri* (4)						
Wisteria floribunda (5)						
Sapium japonicum (2)						
Rhus ambigua (3)						
Rhus trichocarpa (12)						
Acer crataegifolium (2)						
Acer diabolicum (10)						
Acer japonicum (277)						
Acer micranthum (393)						
Acer miyabei (6)						
Acer mono (56)						
Acer mono var. *glaucum* (3)						
Acer mono var. *marmoratum* (1)						
Acer nikoense (35)						
Acer palmatum (1)						
Acer palmatum var. *amoenum* (15)						
Acer rufinerve (102)						
Acer sieboldianum (1)						
Acer tenuifolium (1)						
Aesculus turbinata (1)						
Ilex macropoda (3)						
Celastrus orbiculatus (2)						
Buxus microphylla var. *japonica* (27)						
Berchemia berchemiaefolia (15)						
Berchemia racemosa (12)						
Parthenocissus tricuspidata (3)						
Vitis coignetiae (2)						
Vitis flexuosa (1)						
Tilia japonica (358)						

第10表　（つづき）
Table 10　(continued)

Climatic zone / Shiobara species	Sub-arctic	Cool temperate		Warm temperate		Sub-tropic
		Up.	Low.	Up.	Low.	
Myriophyllum spicatum (75)						
Cornus controversa (15)						
Cornus kousa (88)						
Acanthopanax sciadophylloides (12)						
Aralia cordata (2)						
Kalopanax septemlobus (18)						
Clethra barbinervis (392)						
Enkianthus campanulatus (84)						
Lyonia ovalifolia var. *elliptica* (243)						
Rhododendron degronianum (68)						
Rhododendron kaempferi (82)						
Rhododendron quinquefolium (65)						
Rhododendron wadanum (186)						
Tripetaleia paniculata var. *latifolia* (8)						
Pterostyrax hispida (2)						
Styrax japonica (12)						
Styrax obassia (1)						
Fraxinus lanuginosa (75)						
Ligustrum tschonoskii (1)						
Galium kinuta (3)						
Viburnum dilatatum (11)						
Viburnum furcatum (76)						
Viburnum phlebotrichum (3)						
Viburnum sieboldii (20)						
Viburnum wrightii (8)						
Artemisia princeps (4)						
Chrysanthemum sp. cf. *C. makinoi* (1)						
Potamogeton maackianus (3)						
Potamogeton perfoliatus (2)						
Sasa sp. cf. *S. kurilensis* (1)						
Sasa sp. cf. *S. palmata* (3)						
167 species	5	136	150	87	81	7

第11表　日本における森林帯・暖かさの指数・気候帯の関係.

Table 11　Relation between forest zone, warmth index and climatic zone in Japan.

吉　良（1949）		中　山（1979）	前田・谷本（1986）	
森林帯 Forest zone	暖かさの指数（℃） Warmth index	森林帯 Forest zone	森林帯 Forest zone	気候帯 Climatic zone
常緑針葉樹林 Evergreen coniferous forest	15～45－55	亜寒帯林 Subarctic forest	針葉樹林 Coniferous forest	亜寒帯 Subarctic zone
温帯落葉樹林 Cool-temperate deciduous forest	45—55～85	冷温帯林 Cool-temperate forest	落葉広葉樹林 Deciduous broad-leaved forest	冷温帯 （温帯） Cool-temperate zone
暖帯落葉樹林* Warm-temperate deciduous forest		中間温帯林 Hemitemperate forest		
照葉樹林 Laurel forest	85～180	暖温帯林 Warm-temperate forest	常緑広葉樹林 Evergreen broad-leaved forest	暖温帯 （暖帯） Warm-temperate zone
		亜熱帯林 Subtropical forest	常緑広葉樹林 Evergreen broad-leaved forest	亜熱帯 Subtropical zone

* この森林は暖温帯のうちで寒さの指数－10°C 以下になる地帯に成立する。

This forest zone is in predominance to the site where the coldness index is less than －10°C within the warm-temperate zone.

布しているブナは，表日本のものと裏日本のものとでは一般に葉の大きさが異なり，表日本のものはコハ（小葉）ブナ，裏日本のものはオオバ（大葉）ブナと呼ばれている．塩原産の化石は概して小葉が多く，表日本型気候の影響が大きかったものと言える．塩原層群が堆積した当時から現在までに気候の変化が繰り返し行われ，それに伴って植生も遷移してきたはずであるが，現在の塩原盆地の植生に化石堆積当時と同じ「表日本型を主とし，裏日本型を混じえる」特徴が残されていることは，化石堆積当時と現在とで，地理的条件に大きな差がなかったことを示すものである．

VI.2　花粉化石による考察

第8図に示したように，花粉分析の結果から層準による花粉組成の垂直変化が見られ，特に広葉樹の *Alnus* と *Fagus* の増減から化石堆積当時の環境変化を読み取ることができる．*Alnus* は樹木の中では比較的乾燥に強い陽樹が多く，*Fagus* は，III.3 植生の項で述べたように，年平均の降水量が約 1,200 mm 以上といった湿潤な気候条件下で極相を作る樹種である．

Fagus が各層準から豊富に産出していることから，この期間は全般にブナを代表とするいわゆるブナ帯林（落葉広葉樹林）が塩原化石湖（湖盆）周辺の山地の広い部分を占めていたことは疑いないが，特に試料 Nos. 3, 4, 6, 8～10 の時代は降水量年平均 1,200 mm 以上，暖かさの指数 85°C 前後の環境のもとで，ブナ林の極相が広がっていたものと推定される．一方，*Alnus* は試料 Nos. 2, 5, 7, 11, 12, で他の層準を上回って出現していることから，この時期にはやや乾燥した環境が推察される．しかし，各層準を通じて特に気温の変動を示す材料は認められていない．

VI.3　大型化石と花粉化石による古植生復元

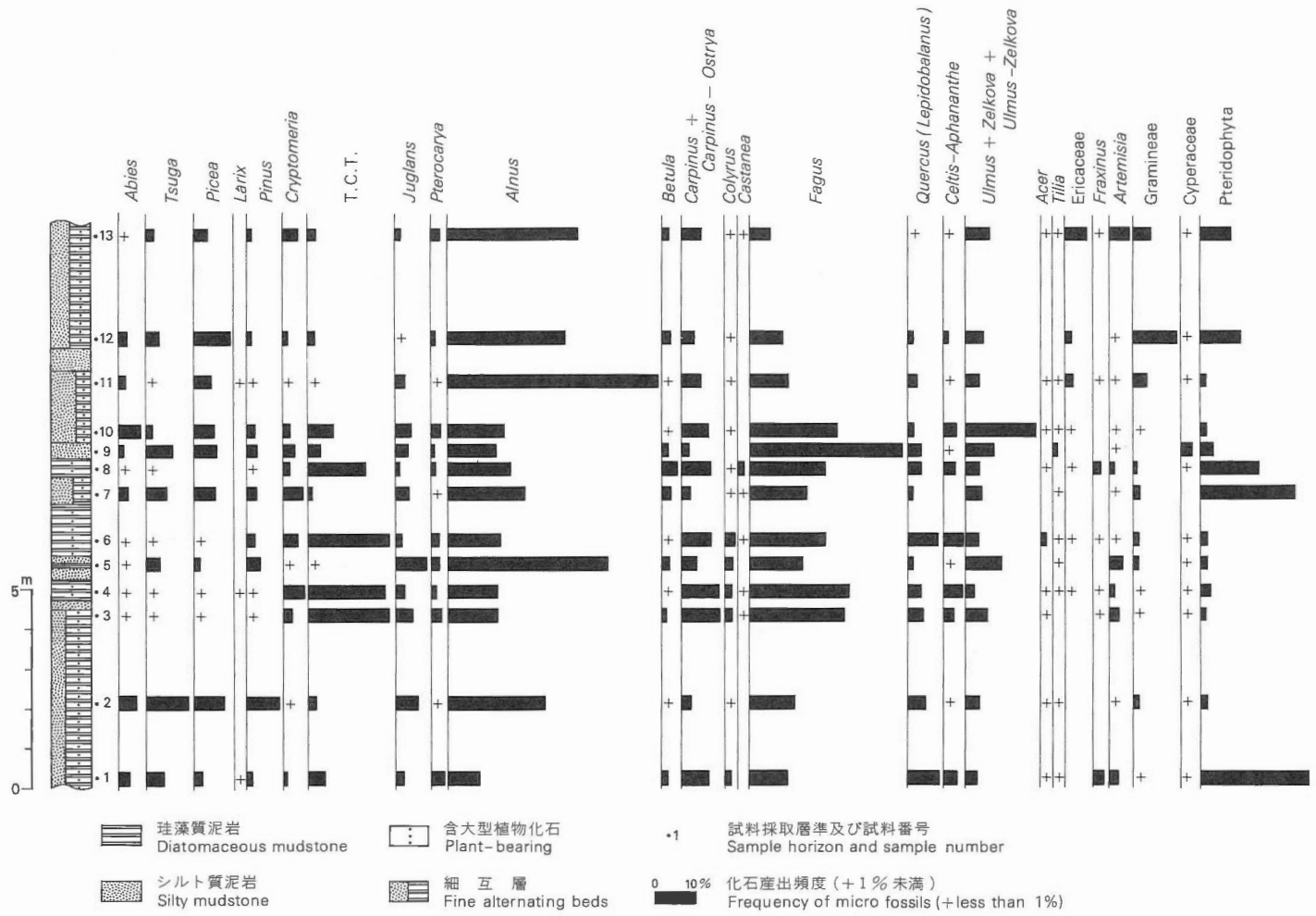
これまでに述べてきた大型化石と花粉化石から予想される植物をもとに，塩原化石植物群堆積当時の植生の復元を以下に試みる．

塩原化石湖と呼ばれている湖盆の水深 4～2 m 付近の水域では，*Potamogeton perfoliatus*（ヒロハノエビモ），*Myriophyllum spicatum*（ホザキノフサモ）が，それよりやや浅い 2～1 m あたりでは *Potamogeton maackianus*（センニンモ）が，そして 1 m 以浅で *Ceratophyllum demersum*（マツモ）と言った水草が生育していた．

また，花粉化石から想定される Cyperaceae（カヤツリグサ科）の *Cyperus*（カヤツリグサ属），*Scirpus*（ホタルイ属）や *Carex*（スゲ属）のうち，湿地を好む多くの多年草が生育し，さらに Gramineae（イネ科）の *Phragmites communis*（アシ）は，世界中の亜寒帯から暖温帯にかけて分布する種であり，湖岸に繁茂していたことは疑いない．

湖周辺地域には *Fagus japonica*（イヌブナ），*Castanea crenata*（クリ），*Alnus firma*（ヤシャブシ），*Betula grossa*（ミズメ），*Carpinus japonica*（クマシデ），*Clethra barbinervis*（リョウブ），*Lyonia ovalifolia* var. *elliptica*（ネジキ）などを優占種として *Abies firma*（モミ），*Cryptomeria japonica*（スギ），*Fagus crenata*（ブナ），*Quercus aliena*（ナラガシワ），*Q. serrata*（コナラ），*Cudrania tricuspidata*（ハリグワ），*Magnolia obovata*（ホオノキ），*Trochodendron aralioides*（ヤマグルマ），*Cercidiphyllum japonicum*（カツラ），*Hamamelis japonica*（マンサク），*Acer crataegifolium*（ウリカエデ），*A. palmatum*（イロハカエデ），*A. rufinerve*（ウリハダカエデ），*Buxus microphylla* var. *japonica*（ツゲ），*Berchemia berchemiaefolia*（ヨコグラノキ）及び花粉化石から想定される *Pinus thunbergii*（アカマツ）など，主として冷温帯下部に分布する落葉広葉樹に，常緑の針葉樹と広葉樹を伴う高木層が形成されていた．

これら高木の間には *Lindera obtusiloba*（ダンコウバイ），*Corylopsis gotoana*（ミヤマトサミズキ），*Pourthiaea villosa*（カマツカ），*Rhododendron kaempferi*（ヤマツツジ），*Viburnum dilatatum*（ガマズミ），*V. sieboldii*（ゴマキ）などの低木層があり，更にそれらの下草として *Davallia mariesii*（シノブ），*Woodsia manchuriensis*（フクロシダ），を含むシダ類や *Boehmeria tricuspis*（アカソ），*Cardiandra alternifolia*（クサアジサイ），*Dumasia truncata*（ノササゲ），*Artemisia princeps*（ヨモギ）が地表



第8図　塩原層群産主要花粉化石変遷図.
Fig. 8　Stratigraphic frequencies of selected microfossils from the Shiobara Group.

を覆っていたものと考えられる．

湖岸から山地に向かって，植生はブナ林で特徴づけられる典型的な冷温帯落葉広葉樹林へと移行していく．これらは冷温帯下部から上部にかけて広い分布を示すもので，*Fagus crenata, F. japonica, Betula schmidtii*（オノオレカンバ），*Quercus mongolica* var. *grosseserrata*（ミズナラ），*Tilia japonica*（シナノキ）などを優占種として，針葉樹の *Picea polita*（ハリモミ），*Tsuga sieboldii*（ツガ），*Pinus parviflora*（ヒメコマツ），*Thuja standishii*（クロベ），広葉樹の *Pterocarya rhoifolia*（サワグルミ），*Alnus firma*（ヤシャブシ），*Carpinus japonica*（クマシデ），*Celtis jessoensis*（エゾエノキ），*Ulmus davidiana* var. *japonica*（ハルニレ），*Cercidiphyllum japonicum*（カツラ），*Stewartia pseudo-camellia*（ナツツバキ），*Sorbus alnifolia*（アズキナシ），*S. commixta*（ナナカマド），*Acer japonicum*（ハウチワカエデ），*A. micranthum*（コミネカエデ），*A. mono*（イタヤカエデ），*Cornus kousa*（ヤマボウシ），*Acanthopanax sciadophylloides*（コシアブラ），*Kalopanax septemlobus*（ハリギリ），*Fraxinus lanuginosa*（アオダモ）などが高木層として繁茂していた．

低木層としては *Alnus pendula*（ヒメヤシャブシ），*Corylus sieboldiana*（ツノハシバミ），*Lindera membranacea*（オオバクロモジ），*L. umbellata*（クロモジ），*Parabenzoin praecox*（アブラチャン），*Hydrangea paniculata*（ノリウツギ），*Rosa multiflora*（ノイバラ），*Stephanandra incisa*（コゴメウツギ），*Enkianthus campanulatus*（サラサドウダン），*Rhododendron degronianum*（アズマシャクナゲ），*R. quinquefolium*（ゴヨウツツジ），*Viburnum furcatum*（オオカメノキ），*V. wrightii*（ミヤマガマズミ）などが生育していた．

さらに，林床には裏日本のブナ林に共存する *Sasa kurilensis*（チシマザサ），*S. palmata*（チマキザサ）が認められているが，塩原化石植物群の構成から考えて，表日本の現生のブナ林に伴って広く分布する *Sasa purpurascens*（スズタケ）も当然生育していたものと思われる．

また，ブナ林にとって地表の湿度を保つうえで重要な役割を果たしている草本類には，シダ類を主体として *Saxifraga fortunei*（ダイモンジソウ），*Aralia cordata*（ウド），*Galium kinuta*（キヌタソウ）や，花粉化石から想定される種類として Cyperaceae と Gramineae の仲間が生育していたであろう．

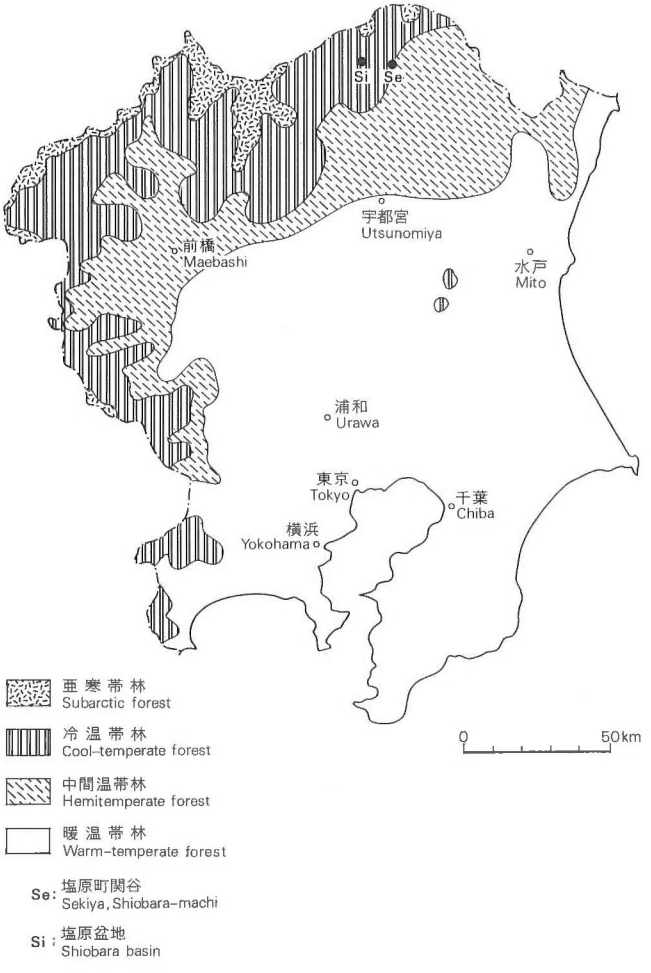
冷温帯落葉広葉樹林は，木性つる植物が多いのも一つの特徴であるが，*Schizophragma hydrangeoides*（イワガラミ），*Actinidia arguta*（サルナシ），*A. polygama*（マタタビ），*Wisteria floribunda*（フジ），*Rhus ambigua*（ツタウルシ），*Berchemia racemosa*（クマヤナギ），*Parthenocissus tricuspidata*（ツタ），*Vitis coignetiae*（ヤマブドウ）などが岩場や大木に絡んでいたことがうかがえる．

大型化石からは亜寒帯固有の植物は発見されていない．しかし，仮に堆積盆周縁部に亜寒帯に相当する山地があったとすれば，その山地の冷温帯上部から亜寒帯（亜高山帯）にかけては，*Sorbus commixta* を主体とした *Alnus maximowiczii*（ミヤマハンノキ），*Betula ermani*（ダケカンバ），*Prunus nipponica*（ミネザクラ）などの落葉広葉樹と，花粉化石から想定される *Abies, Picea, Pinus* などの針葉樹の混交林が発達し，下草としてはシダ植物をはじめ *Saxifraga fortunei, Polygonum cuspidatum*（イタドリ），Cyperaceae の *Carex* の仲間などが地表を覆っていたものと思われる．

Ⅶ. 古 気 候

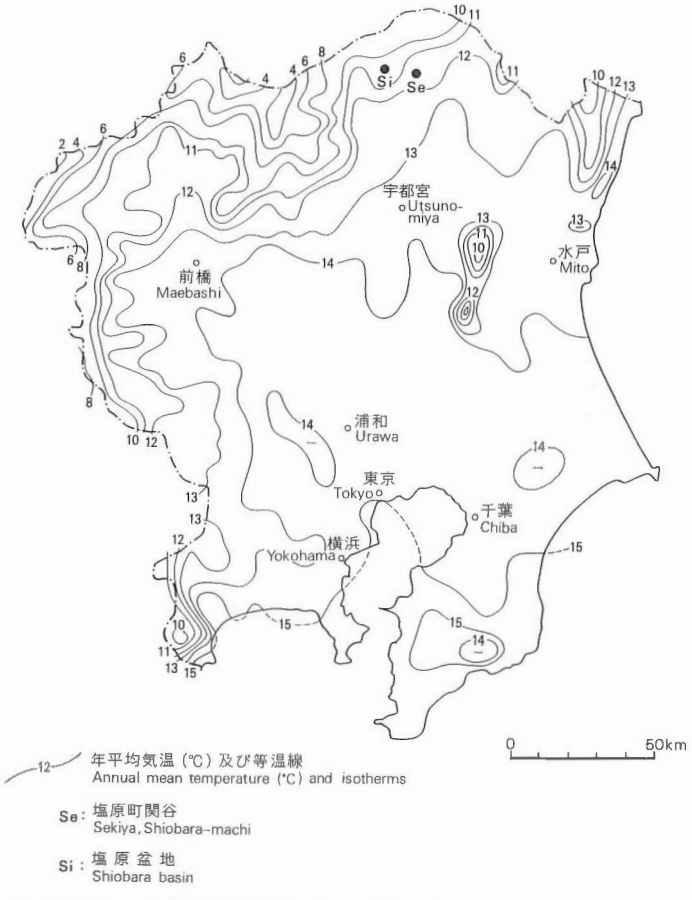
塩原化石植物群堆積当時の気温について，矢部（1929）及び遠藤（1931 a）は現在の日光中禅寺湖周辺とほぼ同じであり，現在より 5～6°C 低かったと考えた．また，小泉（1940）は，塩原化石植物群中には冷温帯下部から暖温帯に普通にみられる樹種が 15 種含まれていることから，同植物群が示す気候は現在と大差はなかったと結論した．しかし，本論の現生植物との比較による研究結果では，現在よりむしろ幾分暖かかったことが推定されるに至った．

塩原化石植物群は，Ⅵ.1 の項で述べたように，主として冷温帯下部の組成を示しており，更に，*Carpinus tschonoskii, Castanea crenata, Fagus japonica* 及び *Quercus serrata* など，中間温帯林の要素



第9図　関東地方の森林帯区分.（青野・尾留川（1968）による）
Fig. 9　Forest zone in the Kanto district. (After AONO and BIRUKAWA, 1968)

も伴っており，同植物群を構成している植物の大部分は中間温帯林の生育域にごく近接した冷温帯下部の環境下に生育していたものと推定された．現在，塩原盆地付近で冷温帯林と中間温帯林の接するところは第9図に示したとおり，塩原盆地の東約10 km，標高約400 mの塩原町関谷付近に位置している．この地点そのものの気象記録はないが，関東地方の年平均気温分布図（第10図）によると，11°Cと12°Cの等温線に挟まれている．関谷の南東約5 kmの所にある農林水産省草地試験場内（標高320 m，北緯36度55分，東経139度58分）の気象観測記録（農林水産省草地試験場，1985）によると同地の年平均気温は12.2°Cであり，同地と関谷（標高400 m）との比高80 mに相当する気温差を前述の気温逓減率を用いて補正すると，関谷付近の現在の年平均気温は11.8°Cとなって，前述の等温線図の示す温度範囲に入る．このことは，言いかえると，関谷付近における冷温帯林と中間温帯林の境界の気温が11°C～12°Cの範囲に入っていて，相互のデータが矛盾していないことを示す．



第10図　関東地方の年平均気温分布図．（青野・尾留川（1968）による）
Fig. 10　Isotherms of annual mean temperature in the Kanto district. (After AONO and BIRUKAWA, 1968)

各植物種の気温に対する感受性が，年代の経過につれて大幅に変わることは極めて考えにくいことから，ここで示された11.8°Cという値を塩原化石植物群堆積当時の年平均気温と推定することが可能である．この値と，現在の塩原盆地の年平均気温10.5°C（宇都宮気象台，1963）と比較してみると，当時は現在よりも1°C強暖かかったことになる．

木の葉化石園内に露出している塩原層群上部の大型化石を豊富に含む泥岩について行った花粉分析結果からは，やや乾燥した時期が数回訪れたことがうかがえるが，概して化石植物群堆積当時はブナ林が生育するに充分な湿潤気候が推定される．また，化石植物群の組成に一部裏日本型気候を指示する要素が含まれていることから，冬期の積雪もあったと考えられる．しかし，化石植物群全体を通観した場合には，特に気温の変化を示す特徴が見られないことから，同植物群が堆積していた期間，塩原化石湖周辺の気温は安定していたものと判断される．

Ⅷ. 地 質 時 代

塩原層群の地質時代については，かつて鮮新世と考えられたこともあったが（NATHORST, 1888；金原，1900），その後，矢部（1929），遠藤（1931 a），ENDO（1934 b, 1935），小泉（1940），AKUTSU（1964）などによって再検討された結果，現在では更新世とする考えでは一致している．

塩原化石植物群は，*Keteleeria davidiana*（シマモミ），*Glyptostrobus pensilis*（イヌスギ），*Metasequoia disticha*（メタセコイア），*Juglans megacinerea*（オオバタグルミ）など，更新世前期まで日本に生存が確認されているが，その後日本列島から消滅してしまった樹種や絶滅種が1種も含まれておらず，すべて現生種からなっていることから，その形成期が大阪層群でいうメタセコイア消滅期以降の時代であることはほぼ確実である．また，同植物群はその組成から更新世の間氷期に形成されたことは明らかであるが，どの間氷期のものであるか決め手に乏しい．

そこで，塩原化石植物群を含む塩原層群上部に挟在する，あるいは同層群を覆っている安山岩のK-Ar法による全岩年代測定を試み，約30万年前の値が得られた（板谷ほか，未公表資料）．この値はこれまで論じてきた塩原化石植物群の古生物学的情報から想定される更新世中期以降という年代と矛盾するものではない．したがって，塩原化石植物群の形成年代は前述のデータ及び考察に示されたように，約30万年前の間氷期である可能性が極めて高い．

Ⅸ. 結　　論

以上の各項を総合して得られる本研究の結論は，要約すれば以下のとおりである．

1. 塩原層群（湖成層）上部から産する11,494点の標本から同定された大型植物化石は51科104属171種，花粉化石はこれとほぼ重複する50種類である．大型化石と花粉化石の組合せにより，大型化石として残りにくい草本類は花粉化石により，また花粉化石には現れにくい虫媒花植物の存在は大型化石により，それぞれその存在を推定できることを利用して，より正確な古植生を復元した．
2. 復元された当時の植物相は，塩原化石湖周辺地域のクリ・イヌブナを主体とした冷温帯下部の落葉広葉樹林と，その背後の盆地斜面を広く覆っているブナ林で代表される冷温帯落葉広葉樹林で特徴づけられた．
3. 花粉化石による層準ごとの詳しい検討から，塩原化石植物群の形成期間全体を通じて湿潤な気候であったことが分かるが，その中にあって，やや乾燥した気候が数回到来したこと．また，堆積盆地内は現在と同じく，表日本型気候が卓越するなかで，冬期には裏日本型気候の影響が及んでいたことが読み取れる．
4. 塩原化石植物群の形成期についての通説は，更新世の氷期であるとされてきた．しかし，大型・花粉の両化石種を通じて，氷期形成を証拠だてる極低温要素は全くなく，むしろ現在，塩原を含む関東山地北部一帯で観察される植物相と良い一致を示している．したがって，塩原化石植物群は間氷期に生育していたことは確実で，氷期形成説は否定される．
5. 前述の間氷期の年代は，塩原層群と時期を同じくして活動した高原火山の安山岩について測定した全岩K-Ar年代値から，約30万年前と推定される．

更新世の火山活動に伴って形成された小湖盆は本邦各地にみられるが，そこに堆積した化石植物群については，現在に至るまで相当の部分が記載されないまま残っている．今後，更にこれら残された各地の更新世化石植物群についてその内容を明らかにし，各地の植生と古環境の復元に努力したい．

X. Systematic Descriptions

In the following systematic descriptions, the repositories of the specimens are indicated by the following symbols or abbreviation: SFPG (Shiobara Fossil Plant Garden, Tochigi), YNU (Geological Institute, Yokohama National University, Yokohama), IGPS (Institute of Geology and Palaeontology, Tohoku University, Sendai), KYOTO UNIV. (Department of Botany, Kyoto University; no original registered number has been given), GSJ (Geological Survey of Japan, Tsukuba).

PTERIDOPHYTA

Family Davalliaceae

Genus *Davallia* SMITH

Davallia mariesii MOORE
Pl. 1, figs. 1, 2

Description: Fronds deltoid or deltoid-ovate, 5 to 12 cm long and 5 to 10 cm wide; tripinnate, with 6 to 10 pairs of pinnae; pinnule irregularly dichotomously branched, oblong to lanceolate 2 to 4 mm long, 1 mm wide; veins stout.

Remarks: Several fronds with almost complete one were obtained from the Shiobara fossil flora. These specimens are identical to the modern *Davallia mariesii* by the characters described above. The living species is distributed in the cool- to warm-temperate zones through Honshu to Kyushu, Japan and extends to Korea and China.

Collection: SFPG nos. 163, 172

Family Aspidiaceae

Genus *Athyrium* ROTH

Athyrium yokoscense (FRANCHET et SAVATIER) CHRIST
Pl. 1, fig. 3

Description: Fronds bipinnate; pinnae linear to lanceolate, 2 to 4 cm long, 1.0 to 1.2 cm wide at the middle part, deeply pinnatifid; pinnules oblong, somewhat inequilateral, 6 to 10 mm long and 2 to 3 mm wide at the middle portion, acute at apex, margin serrulate; veins pinnately arranged.

Remarks: Four fragmentary fronds are identical with *Athyrium yokoscense* in their falcately oblonged pinnules with serrulate margin and pinnately arranged venation characters. This species is widely distributed in the cool- to warm-temperate zones from Hokkaido to Kyushu, Japan and extends to Sakhalin, Korea and China.

Collection: SFPG no. 164.

Genus *Polystichum* ROTH

Polystichum tripteron (KUNZE) PRESL

Pl. 1, fig. 4

Description : Lamina pinnate, pinnae oblong-triangular, slightly falcate, acute at apex, obliquely and broadly cuneate at base, 3.2 cm long and 0.9 cm wide ; margin sharply serrate ; veins diverging from the costa pinnately and forked once or twice near the margin.

Remarks : A single fragmental frond specimen is referable to *Polystichum tripteron* in its characteristic shape of pinnae and venations which is widely distributed in the cool- to warm-temperate zones from Hokkaido to Kyushu, Japan and extends to Korea and China.

Collection : SFPG no. 165

Genus *Woodsia* R. BROWN

Woodsia manchuriensis HOOKER

Pl. 1, fig. 5

Description : Fronds lanceolate (estimated), length of fronds unknown, width of fronds 2.2 to 3 cm at the middle part, bipinnate ; pinnae ovate to elliptical in general outline, largest pinnae 1.5 cm long and 0.7 cm wide at the base, base truncate-auriculate, veins forked ; 6 to 12 sori sunk on the veins of pinnae along the both side of the rachis.

Remarks : Several fertile fronds, though they are incomplete, have characteristic arrangement of sori, and are identical with the modern *Woodsia manchuriensis* which is growing luxuriantly in the cool- to warm-temperate zones of Hokkaido, Honshu, Shikoku and Kyushu, Japan and extends to Korea and China.

Collection : SFPG no. 166.

Woodsia polystichoides EATON

Pl. 1, figs. 6

Description : Fronds pinnate, more than 7 cm long, 2 to 3 cm wide at the middle, linearly elliptical in general out line ; pinnae small 1.4 cm long and 0.4 cm wide, oblong, somewhat falcate, apex obtuse, base truncate-auriculate above and cuneate below ; margin entire ; veins pinnate.

Remarks : Many well preserved sterile frond impressions are closely similar to those of the modern *Woodsia polystichoides* in their characteristic outline of pinna. This modern species is widely distributed in the cool- to warm-temperate zones of East Asia.

Collection : SFPG no. 30.

Family Blechnaceae

Genus *Blechnum* LINNAEUS

Blechnum amabile MAKINO

Pl. 1, fig. 7

Description : Frond pinnate, pinnae linear to oblong in general outline, 1.1 cm long and 0.2 cm wide at the largest one, upper pinnae abruptly shorter ; margin entire, veins obscure.

Remarks : A single fragment frond from the Shiobara fossil flora is referred to this species in the characteristic feature of apical part of the frond. This modern evergreen fern is endemic to Japan.

Collection : SFPG no. 167.

SPERMATOPHYTA

GYMNOSPERMAE

Family Pinaceae

Genus *Abies* MILLER

Abies firma SIEBOLD et ZUCCARINI
Pl. 2, figs. 1, 2

1937. *Abies firma* SIEBOLD et ZUCCARINI; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 305, fig. 1 I-K.
1938. *Abies firma* SIEBOLD et ZUCCARINI; MIKI, *Jap. Jour. Bot.*, vol. 9, p. 219, fig. 4 D.
1940. *Abies firma* SIEBOLD et ZUCCARINI; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 12, fig. 74.
1957. *Abies firma* SIEBOLD et ZUCCARINI; MIKI, *Jour. Inst. Polytech. Osaka City Univ.*, ser. D, vol. 8, figs. H-K.
1962. *Abies firma* SIEBOLD et ZUCCARINI; MIKI and KOKAWA, *Jour. Bot. Osaka City Univ.*, vol. 13, pl. 10, fig. D; pl. 12, fig. F.
1966. *Abies* sp. cf. *A. firma* SIEBOLD et ZUCCARINI; KOKAWA, *Jour. Biol. Osaka City Univ.*, vol. 17, pl. 8, fig. P.
1971. *Abies firma* SIEBOLD et ZUCCARINI; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 22, pl. 4, figs. 2-5.

Remarks : This species is represented by two fragmentary foliage shoots and a single basal part of cone. These fossil specimens resemble those of the modern *Abies firma,* which grows wild mainly in southern Honshu, Shikoku and Kyushu, Japan.

ONOE (1971) described the fossil needles, cone-scales and seeds of this species from an interglacial age of Pleistocene sediments is Ebino city, Miyazaki Prefecture.

KOKAWA (1966) reported needles of *Abies* sp. cf. *A. firma* from the upper Pleistocene Shimoosa Group in Chiba Prefecture. These needle specimens are identical to this species. MIKI (1957) collected the remains of this species from 37 localities in Japan of Pliocene and Pleistocene.

Collection : KYOTO UNIV., SFPG no. 158.

Genus *Larix* MILLER

Larix leptolepis (SIEBOLD et ZUCCARINI) GORDON
Pl. 2, figs. 3-5

1938. *Larix Kaempferi* (LAMB.) CARRIERE; MIKI, *Jap. Jour. Bot.*, vol. 9, p. 228, pl. 3, figs. A-C.
1948. *Larix kaempferi* (LAMB.) CARRIERE; MIKI, *Min. and Geol.*, no. 2, fig. E.
1956. *Larix leptolepis* (SIEBOLD et ZUCCARINI) GORDON; MIKI, *Bot. Mag. Tokyo*, vol. 69, pl. 13, fig. H.

1957. *Larix kaempferi* (LAMB.) CARRIERE; MIKI, *Jour. Inst. Polytech. Osaka City Univ.*, ser. D, vol. 8, p. 233, pl. 1, fig. C.

1985. *Larix kaempferi* (LAMB.) CARRIERE; SUZUKI, *Trans. Proc. Palaeont. Soc.*, N. S., no. 137, p. 69, pl. 9, figs. 1-13.

Remarks: The present species consists of a shoot with leaves and cones and some bundle of leaves. The leaves are characterized by following features: acicular, 2 cm long, apex acute, more than 25 leaves bundled and spread radially. The examined species is identical to the modern *Larix leptolepis* which is restricted to highlands of central Honshu, Japan.

Collection: SFPG nos. 3, 6, 21.

Genus *Picea* A. DIETRICH

Picea polita (SIEBOLD et ZUCCARINI) CARRIERE

Pl. 2, figs. 6-8

1937. *Picea polita* (SIEBOLD et ZUCCARINI) CARRIERE; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 306, fig. 1-H.

1957. *Picea polita* (SIEBOLD et ZUCCARINI) CARRIERE; MIKI, *Jour. Inst. Polytech. Osaka City Univ.*, ser. D, vol. 8, p. 244, pl. 4, fig. A.

1968. *Picea polita* (SIEBOLD et ZUCCARINI) CARRIERE; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 42, pl. 1, fig. 4.

1971. *Picea polita* (SIEBOLD et ZUCCARINI) CARRIERE; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 22, pl. 4, figs. 6, 7.

Remarks: This species is represented by three foliage shoots with many needles, a cone-scale and a lot of seeds and these specimens are similar to those of the modern *Picea polita* (SIEBOLD et ZUCCARINI) CARRIERE which is growing in the cool-temperate zone of Honshu, Shikoku and Kyushu, Japan.

Collection: SFPG nos. 50, 168, 169.

Genus *Pinus* LINNAEUS

Pinus parviflora SIEBOLD et ZUCCARINI

Pl. 2, figs. 9, 10

1937. *Pinus parviflora* SIEBOLD et ZUCCARINI; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 306, fig. 1A.

1940. *Pinus pentaphylla* MAYR; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 13, figs. 65, 78, 81.

Description: Leaves linear, 3 cm long and in less than 1 mm wide, five in a fascicle, acutely pointed at apex. Cone-scale orbicular in general outline, 1.7 cm high and 1.9 cm wide; stalk 2 mm long; base of scale obtuse, margin entire.

Remarks: Some needles, seeds and a cone are referred to *Pinus parviflora* SIEBOLD et ZUCCARINI by their bundled 5-linear leaves and ovate cone with thick and large cone-scales. Two seeds of the present species were figured by MIKI (1937) from the upper Pliocene *Stegodon* Beds at Akashi City, Hyogo Prefecture. The distribution of the living *Pinus parviflora* SIEBOLD et ZUCCARINI is mainly in the cool-temperate zone from the Kanto district to Kyushu, Japan.

Collection : SFPG no. 41, GSJ F8015.

Genus *Tsuga* CARRIERE

Tsuga sieboldii CARRIERE
Pl. 2, fig. 11

1938. *Tsuga sieboldii* CARRIERE; MIKI, *Jap. Jour. Bot.,* vol. 9, p. 219, fig. 4-F.
1940. *Tsuga sieboldii* CARRIERE; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 13, figs. 64, 68.
1971. *Tsuga sieboldii* CARRIERE; ONOE, *Rep. Geol. Surv. Jap.,* no. 241, p. 23, pl. 4, figs. 8-10.

Description: Leaves linear, 5 to 10 mm long and 2 mm wide; apex emarginate; acute or rounded at base; midrib clear; petiole slender and 1 mm long.

Remarks : A single branchlet with many leaves and several detached ones are referred to *Tsuga sieboldii,* which is now growing in the cool- to warm-temperate zones of Honshu, Shikoku and Kyushu, Japan. MIKI (1938, 1948, 1956, 1957) reported cones, leaves and shoots of this species at many localities from beds of glacial or interglacial ages as at the Uegahara fossil flora.

ONOE (1971) also figured leaves, seeds and cone-scale impressions from the Ebino flora, which indicates warm-temperate climate, in Miyazaki Prefecture.

Collection : SFPG no. 51.

Family Taxodiaceae

Genus *Cryptomeria* D. DON

Cryptomeria japonica D. DON
Pl. 2, fig. 12

1938. *Cryptomeria japonica* D. DON; MIKI, *Jap. Jour. Bot.,* vol. 9, p. 219, fig. 4-C.

Description : Leaves 6 to 8 mm long and 1 mm wide, spirally arranged, slender, falcate; acute at apex, upcurved; decurrent below at base.

Remarks : This species is represented by only one leafy twig collected by Mr. OZAKI of Yokohama National University. Though the twig is short, it can be safely identified the living *Cryptomeria japonica* by the character of leaves form and spirally arrangement.

MIKI (1938) reported the occurrence of twigs of this species from the plant bed near Katada in Shiga prefecture. It seems to be Lower Pleistocene in age, and the climate of the flora might be referred to that of the present time, on account of the existence of abundant evergreen forest trees.

MIKI (1957) found this species in the Uegahara flora, which indicates warm climate interglacial stage of Pleistocene age. The modern *Cryptomeria japonica* is distributed in the cool- to warm-temperate zones of Honshu, Shikoku and Kyushu, Japan.

Collection : YNU 31399.

Family Cupressaceae

Genus *Chamaecyparis* SPACH

Chamaecyparis pisifera (SIEBOLD et ZUCCARINI)

SIEBOLD et ZUCCARINI
Pl. 2, figs. 13, 14

1938. *Chamaecyparis pisifera* ENDL.; MIKI, *Jap. Jour. Bot.*, vol. 9, p. 219, fig. 4-G.
1965. *Chamaecyparis pisifera* ENDL.; SUZUKI and SOHMA, *Sci. Rep. Tohoku Univ.*, 4th Ser., vol. 31, no. 3, pl. 1, figs. 8, 9.

Description : Cones small, globose, 5 to 6 mm in diameter; cone-scale woody, peltate, decussately arranged about 2 mm thick.

Remarks : The above specific description of *Chamaecyparis pisifera* is based on only two nearly complete cones. Though no fossil leaf has been collected, the cones belong doubtlessly to this species in their small globose outline, peltate and decussately arranged cone-scales. This species is new described one in the Shiobara fossil flora.

MIKI (1938, 1948, 1957) reported many cones and shoots from various localities of Kinki and its adjacent district of the Pliocene and Pleistocene sediments.

SUZUKI and SOHMA (1965) figured fossil cones and twigs from the Late Pleistocene Ootsuki formation in Koriyama basin, Fukushima Prefecture.

Collection : SFPG no. 145, 194.

Genus *Juniperus* LINNAEUS

Juniperus rigida SIEBOLD et ZUCCARINI
Pl. 2, fig. 15

Description : Leaves ternate, 1.2 to 1.5 cm long, slender, often curved, sharp tips.

Remarks : Only one terminal part of shoot with several leaves is identical to the living *Juniperus rigida* in the ternate arrangement of leaf and needle-like leaf form. This needle juniper is widely found in the cool- to warm-temperate zones of Honshu, Shikoku and Kyushu in Japan as well as Korea and northern China. It grows well even at rocky places.

Collection : SFPG no. 195.

Genus *Thuja* (GORDON) CARRIERE

Thuja standishii (GORDON) CARRIERE
Pl. 2, figs. 16, 17

1888. *Thuites* sp.; NATHORST, *Pal. Abh.*, vol. 4, no. 3, p. 31, pl. 9, fig. 19.
1937. *Thuja japonica* MAXIMOWICZ; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 308, fig. 1-D.
1940. *Thuja standishii* (GORDON) CARRIERE; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 13, figs. 72, 77.
1954. *Thuja standishii* (GORDON) CARRIERE; TAKAHASHI, *Mem. Fac. Sci. Kyushu Univ.*, ser. D. vol. 5, no. 1, p. 53, pl. 1, fig. 3.
1971. *Thuja standishii* (GORDON) CARRIERE; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 23, pl. 4, figs. 12-14.

Description : Branchlets flattened, with leaves scale-like, in four ranks decussately arranged; the dorsiventral pairs flattened, rhombic with obtuse tip, smaller than lateral ones; lateral pairs triangular, about 1 mm long, pointed tip, incurved; lateral ones fairly covering basal part of facial ones. Cones ovate-globose, woody, 8 to 10 mm long and 5 to 6 mm wide.

Remarks : Many leafy branchlets and a single fruiting shoot with three cones are quite identical with the living *Thuja standishii,* which is distributed in the cool-temperate forests of Honshu and Shikoku, and is most common in northern to central Honshu, at altitudes of 400 to 2,000 m.

The fossil shoots of *Thuja japonica* MAXIMOWICZ (Syn. *Thuja standishii*) were reported from the *Stegodon* beds in Hyogo Prefecture by MIKI (1937). ONOE (1971) also figured leafy twigs from the interglacial age of Pleistocene in Ebino City, Miyazaki Prefecture.

Collection : SFPG no. 38, GSJ F8016.

ANGIOSPERMAE

Family Juglandaceae

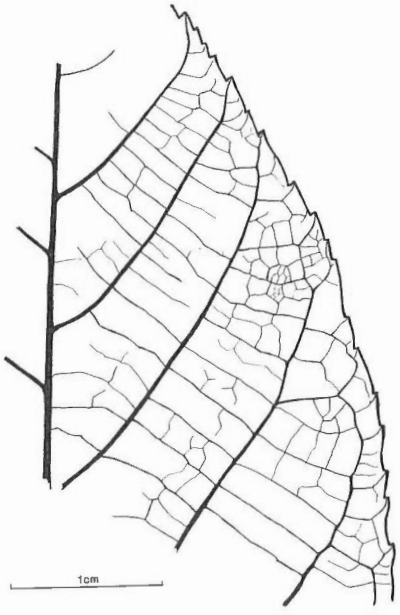
Genus *Juglans* LINNAEUS

Juglans ailanthifolia CARRIERE

Pl. 3, fig. 3; text-fig. 1

1971. *Juglans mandshurica* var. *sieboldiana* MAKINO; ONOE, *Rep. Geol. Surv. Jap.,* no. 241, p. 24, pl. 4, figs. 15, 16.

Description : Leaflet elliptical, apex and base missing, about 14 cm (estimated) and 5.5



Text-fig. 1 Venation characters of fossil *Juglans ailanthifolia* CARRIERE. YNU 31400, ×2.

cm wide (estimated), midrib stout, somewhat arched; secondary nerves rather slender, about 14 subalternate pairs, diverging from the midrib at angles of about 60 degrees at the basal half and about 45 degrees at the upper one, most of secondaries camptodromous, craspedodromous near the apex; tertiary veins irregularly percurrent; tertiary veins in marginal area entering marginal teeth; margin bluntly serrate; texture thin.

Remarks : A single leaflet collected by Mr. OZAKI of Yokohama National University is only specimen in this flora. ENDO (1940) described fossil leaflets of this species (p. 50, pl. 5, figs. 1, 3), but they have argute-serrulate margin and every secondaries make loops near the margin which have been referred to *Pterocarya rhoifolia* SIEBOLD et ZUCCARINI as discussed later.

ONOE (1971) figured a fossil leaflet and a nut from the Pleistocene Ebino flora as the name of *Juglans mandshurica* var. *sieboldiana* MAKINO (Syn. *Juglans ailanthifolia* CARRIERE). The Ebino flora shows warm-temperate climate and is supposed to be of an interglacial age. The modern *Juglans ailanthifolia* is growing in the cool- to warm-temperate forests from Hokkaido at the north to Kyushu at the south.

Collection : YNU 31400.

Genus *Pterocarya* KUNTH

Pterocarya rhoifolia SIEBOLD et ZUCCARINI

Pl. 3, figs. 4, 5

1940. *Juglans sieboldiana* MAXIMOWICZ; ENDO, *Sci, Rep. Tohoku Univ.,* 2nd ser., vol. 21, no. 1, p. 50, pl. 5, figs. 1, 3.

1955. *Pterocarya rhoifolia* SIEBOLD et ZUCCARINI; MIKI, *Jour. Inst. Polytech. Osaka City Univ.,* ser., D, vol. 6, p. 139, pl. 3-F, fig. 4-C.

Description : Leaflet elliptical to oblong in general outline, 8 to 12.5 cm long and 3.3 to 4 cm wide; acute at apex and obliquely obtuse or somewhat cordate at base; margin regularly spacing serrulate; venation pinnate and brochidodremous, midrib almost straight; secondary veins 15 to 20 pairs, subopposite or alternate; tertiary veins percurrent.

Remarks : Many leaves and a single winged nut are identical to living *Pterocarya rhoifolia* SIEBOLD et ZUCCARINI. This species now commonly flourishes along the mountain-streams in the cool-temperate zone of Japan.

ENDO (1940) described some leaflets under the name of *Juglans sieboldiana* MAXIMOWICZ from the Shiobara fossil flora. These leaves, however, are easily distinguishable from *Juglans sieboldiana* by their argute-serrulate margin, and his specimens belong to the present species. The remains of nuts of this living species were reported from Hokkaido and Shikoku by MIKI (1955).

Collection: SFPG no. 170, GSJ F7547.

Family Salicaceae

Genus *Populus* LINNAEUS

Populus maximowiczii HENRY

Pl. 3, fig. 1

Description : Leaf elliptic ovate, about 12 cm long (estimated) and 7.2 cm wide; base

slightly cordate, apex missing; midrib straight, stout; secondary veins rather thin, 9 pairs (estimated), opposite to alternate, diverging at angles of 55 degrees near the base and 35 to 50 degrees at the upper part, forming indistinct marginal loops, entering into marginal teeth; tertiary veins thin, irregularly percurrent; margin irregularly spaced serrate, teeth obtuse; petiole long and stout, 4.3 cm long; texture thin.

Remarks: Leaves of the living *Populus maximowiczii* have many variation in their shape, and the present specimen, though only one leaf lacking one third of upper part, may be included in the present species by their characters.

This species is now distributed in the cool-temperate zone of northeastern Asia.

Collection: SFPG no. 121.

Populus sieboldii MIQUEL
Pl. 3, fig. 2

Description: Leaves variable in general outline and margin, generally oval to orbicular, 2.4 to 9.5 cm long and 1.8 to 8 cm wide; apex cuspidate to broadly acute, base truncate to slightly cordate; primary vein stout at lower part of blade, tapering to apex, nearly straight or zigzag in its upper half; a pair of the basal secondary veins diverging at angles of 30 to 45 degrees from the midvein, turning up and reaching the margin at about a half of the leaf length or more, giving off 5 to 7 tertiary veins; the remaining secondaries 3 to 4 subopposite to alternate pairs, irregularly spaced, giving off some branches of forking near the margin to form marginal loops with the adjacents; tertiary veins in intercostal area percurrent, quaternary veins orthogonal reticulate, ultimate veinlets largely branched twice; margin serrate to sparsely serrate with glandular point; petiole more than 3 cm long.

Remarks: Several leaf specimens obtained in this flora are full of variety in their outline and margin, but they are included in the characteristics of the living *Populus sieboldii* MIQUEL, which is rather common in cool-temperate zone of Japan.

Collection: SFPG no. 52.

Genus *Salix* THUNBERG

Salix integra THUNBERG
Pl. 3, fig. 7

Description: Leaves oblong, 2 to 4 cm long and 0.6 to 1.2 cm wide; obtuse at apex and round or rather cordate at base; margin serrulate; primary vein stout, straight or slightly curved, secondary veins about 9 pairs, irregularly spaced, diverging from the midvein at angles of 60 to 70 degrees, considerably incurved, slenderly creeping up along the margin, connecting with branches of superadjacent secondaries; 1 to 2 intersecondaries leaving from the midvein; petiole 1 to 2 mm long or absent.

Remarks: A small branch with several leaves is identical with this species by the leaves characters described above. The living *Salix integra* THUNBERG is widely distributed in the cool- to warm-temperate zones through Japan, and extends to Korea.

Collection: SFPG no. 155.

Salix sachalinensis FR. SCHMIDT
Pl. 3, fig. 6

Description : Leaves lanceolate, 4 to 8.5 cm long and 0.7 to 1.3 cm wide, acuminate at apex and cuneate at base; midvein slightly curved; secondary veins thin, more than 15 pairs, alternate, irregularly extending and joining branches of superadjacent secondaries to form angular loops; tertiary veins percurrent; quaternary veins obscure; margin serrate to serrulate irregularly; petiole stout, 4 to 6 mm long.

Remarks: Several leaf specimens are referred to *Salix sachalinensis* by their narrow shape, a lot of secondaries and fine serrate margin. This species is very common along the streams throughout Japan, except for Kyushu.

Collection : SFPG no. 40.

Family Betulaceae

Genus *Alnus* GAERTNER

Alnus firma SIEBOLD et ZUCCARINI
Pl. 4, fig. 4

1940. *Alnus pendula* MATSUMURA; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 51, pl. 8, fig. 13.

1940. *Betula ermani* var. *subcordata* KOIDZUMI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 51, pl. 8, fig. 4.

Remarks : Leaves of the living *Alnus firma* SIEBOLD et ZUCCARINI is characterized by tipically ovate outline, acute apex, broadly cuneate base, doubly serrate margin and secondary venation which runs straight from midrib to margin and makes parallel each other. The present excellently preserved impressions in the writer's collection have all the typical characters of *Alnus firma* SIEBOLD et ZUCCARINI, which grows now in the cool- to warm-temperate mountainzones of Honshu, Shikoku and Kyushu, but scarcely found on the Japan-Sea side slopes.

This is a common species in the Shiobara fossil flora. Some leaves described as *Alnus pendula* (ENDO, 1940; pl. 8, fig. 13) and *Betula ermani* var. *subcordata* KOIDZUMI (ENDO, 1940; pl. 8, fig. 4) are included in the present species by all characteristics.

Collection : GSJ F8047.

Alnus hirsuta var. *sibirica* (FISCHER) C. K. SCHNEIDER
Pl. 4, fig. 2

1940. *Alnus hirsuta* var. *sibirica* (FISCHER) C. K. SCHNEIDER; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 50, pl. 10, figs. 3, 22.

1940. *Alnus tinctoria* SARGENT; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 13, figs. 14, 61.

1968. Cf. *Alnus hirsuta* TURCZANINOW; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 46, pl. 2, fig. 1.

Remarks : Several leaf impressions characterized by coarsely doubly serrate and shallowly lobed margin are identical to *Alnus hirsuta* var. *sibirica* which is widely distribut-

ed in Japan and as well as Korea, China and Siberia. It grows usually in the cool- to warm-temperate zones of stream sides of moist plains or of mountainslopes associated with many broad-leaved trees.

KOIDZUMI (1940) described some fossil leaves under the name of *Alnus tinctoria* from the Shiobara fossil flora which is synonym of the present species.

Collection : GSJ F7549.

Alnus maximowiczii CALLIER
Pl. 4, fig. 1

Description : Leaf oval, mucronately acute at apex, slightly cordate at base, 8 cm long and 6 cm wide (estimated); primary vein stout and straight; secondary veins 9 pairs, alternate to subopposite, craspedodromous, diverging from the midvein at angles of about 50 degrees, almost straight, sending off 3 or 4 branches near the margin, tertiary veins fine, percurrent; quaternary veins making orthogonal reticulate; margin duplicately serrulate with acute teeth, teeth at termination of each secondary veins larger than others; petiole thick, 1.3 cm long.

Remarks : A single but well-presserved leaf specimen has been found. The present material is closely similar to *Alnus maximowiczii* CALLIER which is a representative species of the alpine shrub in northern Japan especially on such sunny sites as land-slided slopes and bald hills of low altitude. This species is new record of the fossil from the Shiobara group.

Collection : SFPG no. 53.

Alnus pendula MATSUMURA
Pl. 4, fig. 3

1940. *Alnus pendula* MATSUMURA; ENDO, *Sci. Rep. Tohoku Univ.,* 2nd ser., vol. 21, no. 1, p. 51, pl. 8, figs. 5, 8, 16.

Description : Leaves narrow elliptic, 5 to 12 cm long and 1.8 to 3.3 cm wide; elongate-acuminate at apex and cuneate at base; primary nerves stout; secondary nerves 16 to 20 alternate pairs, almost parallel each other; margin serrate with acuminate tip.

Remarks : The present species is based on a few nearly complete leaves and some fragmentary specimens. The examined specimens are characterized by bollowing features; narrowly elliptical outline, a number of secondaries, acuminate apex and acute base, and they are identical to the living *Alnus pendula* MATSUMURA.

ENDO (1940) described fossil leaves, fruits and ament of this species from the same locality.

Alnus pendula is confined to the Japan-Sea side of Hokkaido and Honshu, in striking contrast to the area of *Alnus firma.*

Collection : GSJ F8046.

Alnus sp. (fruit)
Pl. 4, fig. 5

Description : Fruit suborbicular to elliptical, 1.3 to 1.5 cm long and 1.1 to 1.2 cm wide;

round at apex and base; petiole stout, 3 to 7 cm long.

Remarks : Some fruiting branchlets belong to the Genus *Alnus* and they may be referred to one of the species described above. Among them, the fossil fruits are more similar to *A. firma* and *A. hirsuta* var. *sibirica* in their outline and size.

Collection : SFPG no. 171.

Genus *Betula* LINNAEUS

Betula davurica PALLAS

Pl. 4, fig. 6; text-fig. 2

Description : Leaves ovate to rhombic ovate, 2.5 to 7 cm long and 1.2 to 2.8 cm wide; acute or acuminate at apex, broadly cuneate, rounded or truncaste at base; unequally dentate-serrate on the margin, gland-dotted on the tip of the teeth; venation pinnate, craspedodromous; midrib moderate, almost straight; secondary veins 5 to 7 subopposite pairs, ascending and terminating into marginal serrations; tertiary veins random reticulate; petiole 5 to 8 mm long.

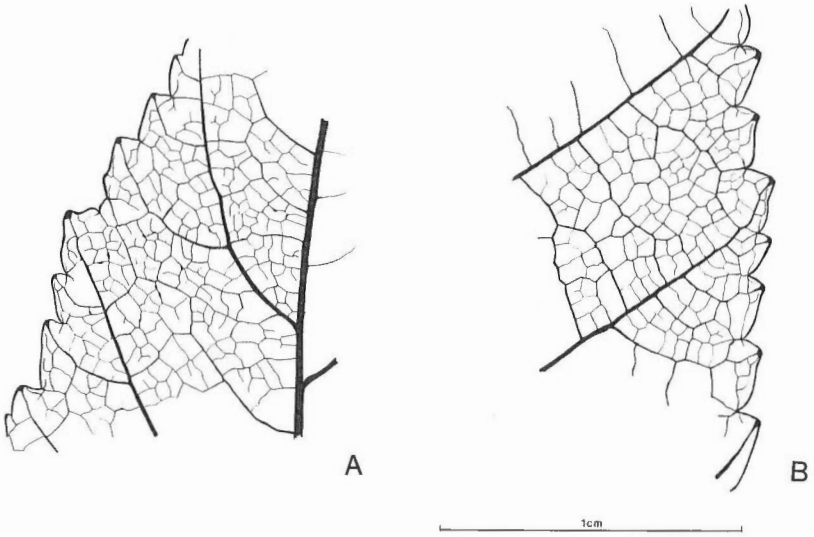
Remarks : Some complete leaves are referred to *Betula davurica*. This living birch is widespread in the continent of northeastern Asia and disjunctively distributed in central Honshu and Hokkaido. It grows scatteredly at open sunny places in the cool-temperate zone. The present species in new record of the fossil from the Shiobara group.

Collection : GSJ F8045.

Betula ermani CHAMISSO

Pl. 4, fig. 7

Description : Leaf ovate, 4.8 cm long and 2.9 cm wide; acuminate at apex and slightly



Text-fig. 2 Venation characters of fossil and related extant species (All figures are ×4)
A. *Betula davurica* PALLAS. GSJ F8045.
B. *Betula davurica* PALLAS. (Leaf of the extant species for comparison)

cordate at base; margin doubly serrate; venation pinnate, craspedodromous; primary vein moderate; secondary veins 6 alternate pairs, almost straight, all of the secondaries terminating at the margin, tertiary veins obscure; petiole 6 mm long.

Remarks : Only one complete and another fragmentary leaf impressions have been found from the Shiobara group. The present specimens are rather similar to the existing species by their ovate foliar shape, slightly cordate base and doubly serrate margin. The living species growing now in the subarctic to cool-temperate zones of Hokkaido, Honshu and Shikoku in Japan.

Collection : SFPG no. 139.

Betula grossa SIEBOLD et ZUCCARINI
Pl. 4, figs. 8-10

1888. *Betula sublenta* NATHORST; NATHORST, *Pal. Abh.*, vol. 4, no. 3, p. 32, pl. 10, fig. 1.
1940. *Betula grossa* SIEBOLD et ZUCCARINI; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 13, fig. 23.
1940. *Betula grossa* SIEBOLD et ZUCCARINI; ENDO. *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 52, pl. 8, fig. 22.
1940. *Betula sollennis* KOIDZUMI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 54, pl. 4, fig. 2; pl. 8, fig. 21; pl. 9, fig. 7.
1971. *Betula* sp.; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 24, pl. 4, fig. 20.

Remarks : The present materials are one of the most abundant in the Shiobara fossil flora and occupied about 5% in the unmber of total specimens. The living species has many varieties in its leaves in size and outline and fossil leaves from the Shiobara fossil flora showed also same tendency.

The modern species is endemic to Japan and widely found in the cool- and warm-temperate forests except Hokkaido.

The cone-scale specimen of *Betula* figured by ONOE (1971) from the Ebino fossil flora is identical to those of the present species.

Collection : GSJ F8017, 8018, 8064.

Betula maximowicziana REGEL
Pl. 5, figs. 1-3

1940. *Betula maximowicziana* REGEL; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 52, pl. 5, figs. 9-11, 15; pl. 10, figs. 13, 20; pl. 11, fig. 11
1968. *Betula maximowicziana* REGEL; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 46, pl. 2, fig. 8.

Remarks : Some well preserved leaves, seeds and cone-scales were examined. The leaves of the present specimens are characterized by large size, orbicular to oval outline, deeply cordate base and subduplicately denticulate margin with long linear tips. The present species is identical with the living *Betula maximowicziana* REGEL growing in the cool-temperate zone of northern Japan.

Collection : GSJ F7554, 8065, 8066.

Betula nikonesis KOIDZUMI
Pl. 5, fig. 7

Description : Leaves ovate to triangularly ovate, about 7 cm long and 3.5 cm wide; attenuate at apex and rounded or subcordate at base; margin doubly serrate; venation pinnate, craspedodromous; primary vein moderate; secondary veins almost straight, all of the secondaries termination at the margin, about 14 alternate or subopposite pairs, parallel each other; tertiary veins obscure.

Remarks : This species is based on a few almost complete leaf specimens. They are closely similar to *Betula nikoensis* KOIDZUMI which is native in central Honshu, especially in cool-temperate zone of the Nikko mountainous area. These fossil specimens are also similar to narrower leaves of *Betula grossa* SIEBOLD et ZUCCARINI, which has many variation in leaf forms.

The writer has referred the present materials to *Betula nikoensis* KOIDZUMI while slight ambiguity has been remaining on the identification.

Collection : SFPG no. 154.

Betula platyphylla var. *japonica* (MIQUEL) HARA

1940. *Betula japonica* SIEBOLD; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 52, pl. 4, fig. 12.

1940. *Betula taushii* KOIDZUMI; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 14.

Remarks : ENDO (1940) figured *Betula japonica* SIEBOLD. KOIDZUMI (1940) discussed on *Betula taushii* KOIDZUMI from the Shiobara fossil flora, and they becomes to synonym of the present species. The living species is growing in the cool-temperate zone of northern Japan.

Collection : IGPS Reg. no. 60920.

Betula schmidtii REGEL
Pl. 5, figs. 4-6

1888. *Alnus* or *Betula* sp.; NATHORST, *Pal. Abh.*, vol. 4, no. 3, p. 31, pl. 10, figs. 2, 3, 5, 6.

1940. *Betula schmidtii* REGEL; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 53, pl. 7, figs. 6, 8, 11; pl. 8, fig. 11; pl. 12, fig. 4.

1940. *Betula schmidtii* REGEL; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 14, figs. 12, 28, 36, 41.

1940. *Corylus sieboldiana* BLUME; KOIDZUMI, (part) *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 15, figs. 7, 19, 21, 30, 33.

Remarks : The present materials, which is one of the most abundant species in the Shiobara fossil flora, are identical with the living *Betula schmidtii* REGEL. It is distributed from continental northeastern Asia to northern and central Honshu. KOIDZUMI (1940) figured *Corylus sieboldiana* BLUME from the collection of Kyoto University. The writer reinvestigated them and found some materials described *Corylus sieboldiana* were identical with the present species in the characteristic features of leaves' form, marginal serration and secondary veins.

Collection : GSJ F8019, 8067, 8068.

Betula sp. (ament)
Pl. 5, fig. 8

Remarks : This amentaceous specimenis assigned to *Betula* with some hesitation, because most species of *Betula* have tale-like ament and are difficult to identify only by ament. It may be referred to male flower of *Betula* and one of the species described above.

Collection : SFPG no. 178.

Genus *Carpinus* LINNAEUS

Carpinus cordata BLUME
Pl. 5, figs. 9, 10

1940. *Carpinus cordata* BLUME ; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 54, pl. 7, figs. 5, 9, 10, 13, 19.

1940. *Carpinus erosa* BLUME ; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 15, fig. 11.

Remarks : The present species, represented by leaves and bracts, is not rare in this flora. Leaves of the examined specimens have oblong or broadly elliptical in foliar shape, acuminate apex, deeply cordate base and fine serration with sharp teeth on margin. Bracts specimens ovate outline acute apex, cuneate base, a few teeth of dentation on upper part of bract and 2 or 3 primary veins. These characters of both leaves and bracts are similar to those of existing species of *Carpinus cordata* BLUME which is one of the commonest deciduous tree along streams in the cool-temperate zone of Japan.

Collection : GSJ F8020, 8039.

Carpinus japonica BLUME
Pl. 5, figs. 11, 12

1888. *Carpinus subjaponica* NATHORST ; NATHORST, *Pal. Abh.*, vol. 4, no. 3, p. 32, pl.9, figs. 12-15.

1940. *Carpinus japonica* BLUME ; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 55, pl. 6, figs. 4, 8, 11, 14, 18 ; pl. 8, fig. 18 ; pl. 9, fig. 14.

1940. *Carpinus distegocarpus* KOIDZUMI ; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 14, figs. 8, 45, 86.

1954. *Carpinus carpinoides* MAKINO ; TAKAHASHI, *Mem. Fac. Sci. Kyushu Univ.*, ser., D, vol. 5, no. 1, p. 55, pl. 2, figs. 1-10 ; pl. 3, figs. 1-5.

Description : Leaves oblong, acuminate apex and rounded at base, 6 to 9 cm long and 3 to 4 cm wide ; margin duplicately serrulate ; primary vein moderate ; secondary veins 18 alternate to subopposite pairs, diverging at angles of 50 to 55 degrees, craspedodromous, running off from the primaries almost straight and ending into larger marginal teeth ; petiole 1 cm long.

Bract ovate in general outline, obtuse at apex and cuneate at base, 2.2 cm long and 1.4 cm wide ; margin entire at basal half of bract and dentate at upper half of it ; 5-primaries running from the base and ending at marginal teeth ; petiole stout, 2 mm long.

Remarks : Many oblong-ovate leaves and bracts are closely similar to the living *Carpinus japonica* BLUME in the chracters mentioned above which is endemic to Japan. It is one of the most common trees from the cool-temperate to the upper part of the warm-temperate zones.

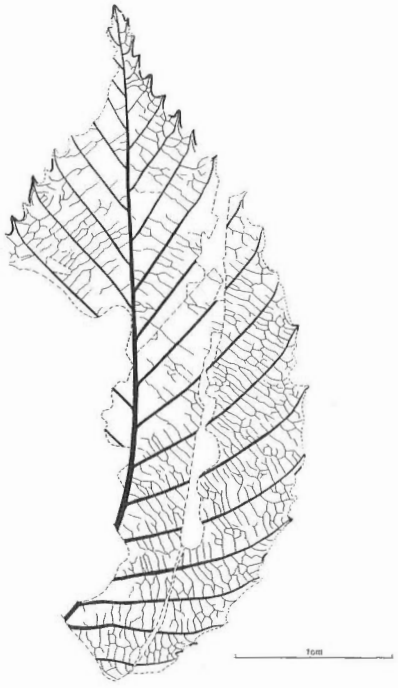
Carpinus distegocarpus KOIDZUMI displayed by KOIDZUMI (1940) from the Shiobara fossil flora and *C. carpinoides* MAKINO from the Oya formation (TAKAHASHI, 1954) are synonym of the examined species. Fragmental leaves and bracts from the Shiobara fossil flora described by NATHORST (1888) under the name of *C. subjaponica* NATHORST are similar to the present species.

Collection : GSJ F8021, 8048.

Carpinus laxiflora (SIEBOLD et ZUCCARINI) BLUME
Pl. 6, figs. 1-3; text-fig. 3

1940. *Carpinus laxiflora* (SIEBOLD et ZUCCARINI) BLUME; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 56, pl. 4, fig. 4.
1940. *Zelkova serrata* MAKINO; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 17, fig. 6.
1971. *Carpinus laxiflora* (SIEBOLD et ZUCCARINI) BLUME; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 25, pl. 4, figs. 23-25.

Remarks : The present species is based on some obovate leaves with attenuate apex and 3-lobed bracts, and is identical to those of produced by the living *Carpinus laxiflora* (SIEBOLD



Text-fig. 3 Venation characters of fossil *Carpinus laxiflora* (SIEBOLD et ZUCCARINI) BLUME. KYOTO UNIV. (sketched from pl. 6, fig. 3), ×2.

et ZUCCARINI) BLUME. This hornbeam is widespread throughout southern Hokkaido, Honshu, Shikoku and Kyushu, as well as in Korea and central China.

A leaf specimen described as *Zelkova serrata* MAKINO from the Shiobara group by KOIDZUMI (1940) has double-serrate margin with acute teeth (text-fig. 3), while leaves of *Zelkova serrata* MAKINO has single-serrate margin with obtuse teeth, and it may be included in this species (pl. 6, fig. 3; text-fig. 3).

No fossil leaf of *Zelkova* has been found from the Shiobara group.

Collection : KYOTO UNIV., GSJ F8024, 8069.

Carpinus tschonoskii MAXIMOWICZ
Pl. 6, figs. 4, 5

1941a. *Carpinus tschonoskii* MAXIMOWICZ; MIKI, *Jap. Jour. Bot.*, vol. 11, p. 268, figs. 10-D, E.
1954. *Carpinus tschonoskii* MAXIMOWICZ; TAKAHASHI, *Mem. Fac. Sci. Kyushu Univ.*, ser., D, vol. 5, no. 1, p. 55, pl. 2, fig. 11; pl. 3, fig. 6.
1968. *Carpinus tschonoskii* MAXIMOWICZ; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 44, pl. 1, figs. 12, 13.
1971. *Carpinus tschonoskii* MAXIMOWICZ; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 25, pl. 4, figs. 18, 19.

Description : Leaves oblong, acute at apex and cuneate at base, 5.4 cm long and 2.6 cm wide; margin doubly serrate with acute teeth; primary vein moderate; secondary veins 10 subopposite to alternate pairs, diverging at angles of 40 to 50 degrees, craspedodromous; tertiary veins obscure; petiole more than 5 mm long.

Bract subulate, 2.4 cm long and 0.6 cm wide, acuminate apex and obliquely cuneate at base; margin of left side of bract entire and the other side dentate; 4 primaries running from the base and entering marginal teeth; petiole stout, 3 mm long.

Remarks : Two nearly complete leaves and a single bract are referred to this species. This hornbeam is very common in the cool- to warm-temperate zones except Hokkaido in Japan.

MIKI (1941a) described many remains of leaves, bracts and seeds assigned to this species from the *Pinus trifolia* beds in central Honshu. ONOE (1971) also figured some bract specimens from Ebino flora in Miyazaki Prefecture, which corresponde to the interglacial age of the Pleistocene.

Collection : SFPG no. 144, GSJ F8070.

Genus *Corylus* LINNAEUS

Corylus sieboldiana BLUME
Pl. 6, fig. 6

1940 *Corylus sieboldiana* BLUME; KOIDZUMI, (part) *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 15, fig. 31.

Description : Leaves obovate in general outline, acute at apex and obtuse or slightly cordate base, 8.4 cm long and 5.4 cm wide; margin duplicately serrate with sharp teeth; primary vein stout, nearly straight; secondary veins 9 subopposite pairs, diverging at angles of 30 to 40 degrees, running off from the midrib straight and ending at larger marginal teeth;

tertiary veins from basal secondaries entering to marginal teeth, tertiaries in intercostal area percurrent; petiole stout, 1.4 cm long.

Remarks : The examined specimens are characterized by obovate foliar shape, low angled secondaries diverging from the midrib and sharp teeth on the margin. The present species is referable to the living *Corylus sieboldiana* BLUME, growing in the cool-temperate zone of northern to central Japan and rarely in Shikoku and Kyushu.

The present species from the Shiobara fossil flora was first reported by KOIDZUMI (1940) based on many leaves and a nut, but some leaves are probably included in *Betula schmidtii* REGEL by their ovate foliar shape (KOIDZUMI, 1940; figs. 7, 19, 21, 30, 33).

Collection : SFPG no. 60.

Family Fagaceae

Genus *Castanea* SIEBOLD et ZUCCARINI

Castanea crenata SIEBOLD et ZUCCARINI

Pl. 6, figs. 7-11; text-fig. 4-C

1940. *Castanea crenata* SIEBOLD et ZUCCARINI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 56, pl. 5, figs. 6-8, 13, 16, 17, 20; pl. 12, fig. 4d.

1940. *Castanea crenata* SIEBOLD et ZUCCARINI; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 15, figs. 3, 32, 47, 52.

1961. *Castanea crenata* SIEBOLD et ZUCCARINI; SUZUKI, *Sci. Rep. Fac. Art. Sci. Fukushima Univ.*, no. 10, p. 56, pl. 12, figs. 5, 6.

Description : Leaves oblong-lanceolate in general outline; apex acuminate; base cordate to auriculate; 6 to 16 cm long, and 2 to 4.8 cm wide; midvein stout and slightly curved; secondary veins 15 to 22 pairs, spacing irregularly, diverging from the midvein at angles of 50 to 60 degrees, curving slightly upwards and distinctly craspedodromous, except those of basal 2 or 4 pairs, which are camptodromous; tertiary veins in intersecondary spaces coarsely and irregularly percurrent; quaternary veins making mainly quadrangular meshes; ultimate veinlets obscure; margin coarsely and irregularly serrate with slender pointed teeth except the basal part; petiole stout 0.5 to 1.2 cm long; texture membranaceous.

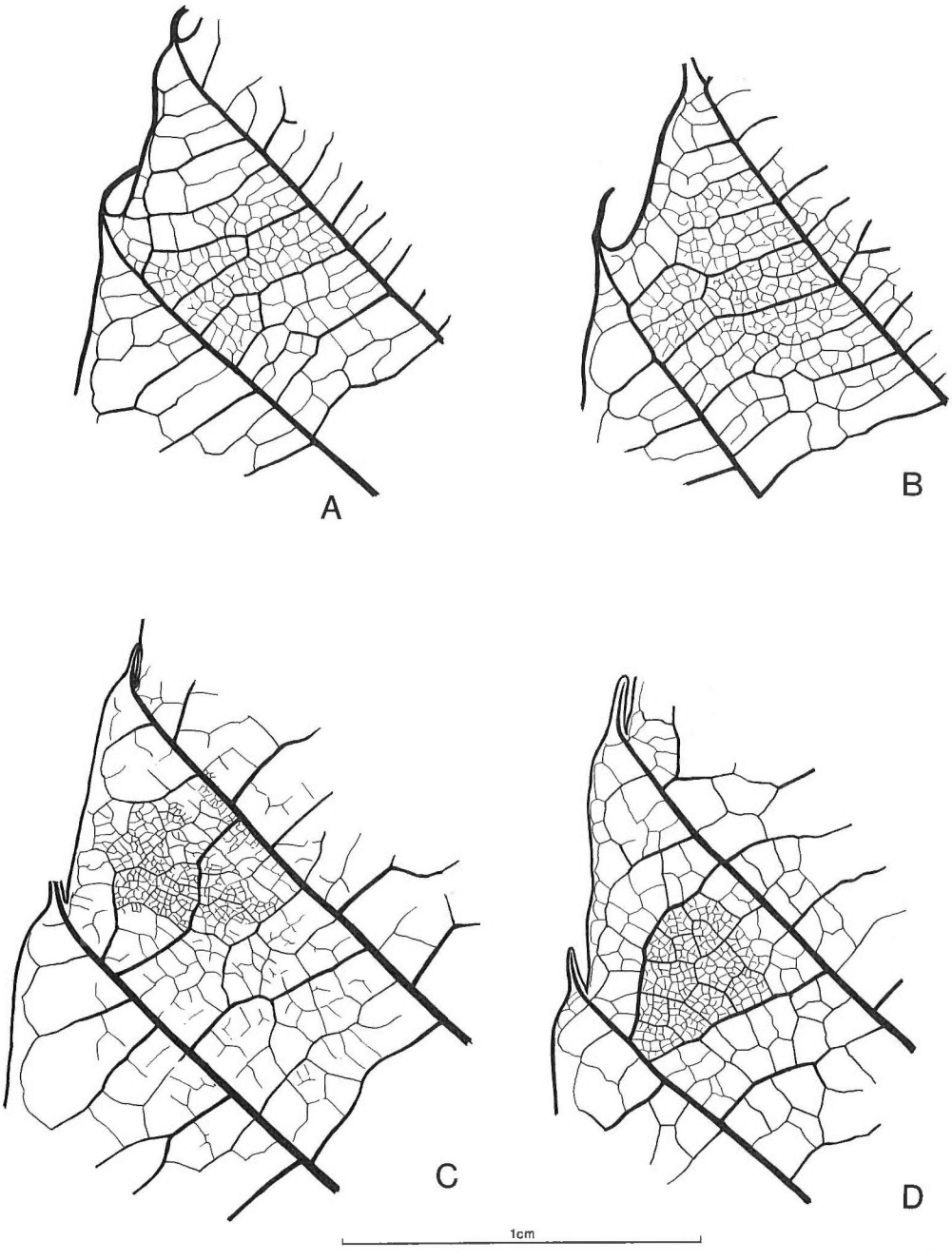
Nuts broadly ovate in shape, apex pointed, base rounded, 2.5 cm wide and 2.9 cm long.

Burs 1.5 to 3.5 cm in diameter, densely crowded with slender sharp spines outside, prickles 1 to 2 cm long.

Ament more than 11 cm long, tapered at apice, covered with crowded flower-clusters from base to apex.

Remarks : The present species, consisted of leaves, nuts, burs and aments, is closely allied to the existing species of the Japanese Islands. Only three aments, three burs and three nuts were found, but leaves were abundant in the flora.

At a glance, the leaves of this species resemble to those of the living *Quercus acutissima* CARRIERE and *Q. variabilis* BLUME in their oblong-lanceolate outline and serration with slender pointed marginal teeth, but studied specimens are different from the latters by auriculate base and irregularly arranged secondary veins. Moreover, *Castanea crenata* has coarser spaced tertiary veins and finer net veins than other two species (text-fig. 4-A, B). The extant *Castanea crenata* SIEBOLD et ZUCCARINI is widely distributed in the cool- to warm-temperate zones from southwestern Hokkaido to Kyushu, Japan.



Text-fig. 4 Venation characters of fossils and related extant species (All figures are ×5)
A. *Quercus acutissima* CARRUTHERS. (Leaf of the extant species for comparison)
B. *Quercus variabilis* BLUME. (Leaf of the extant species for comparison)
C. *Castanea crenata* SIEBOLD et ZUCCARINI. GSJ F7538.
D. *Castanea crenata* SIEBOLD et ZUCCARINI. (Leaf of the extant species for comparison)

Collection : SFPG no. 31, GSJ F7538, 8022, 8023.

Genus *Fagus* LINNAEUS

Fagus crenata BLUME
Pl. 7, figs. 1-6

1888. *Fagus sylvatica* L. *fossilis* ; NATHORST, *Pal. Abh.*, vol. 4, no. 3, p. 33, pl. 9, figs. 1, 2 ; p. 37, pl. 12, figs. 5-10.

1888. *Fagus sylvatica* L. var. *asiatica* DC. *fossilis* ; NATHORST, *Pal. Abh.*, vol. 4, no. 3, p. 37, pl. 12, figs. 1-4.

1937. *Fagus crenata* BLUME ; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 313, figs. 3, I-J.

1940. *Fagus crenata* BLUME ; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 57, pl. 6, figs. 2, 3, 6, 9, 13, 16, 20, 23, 24 ; pl. 12, fig. 4b.

1940. *Fagus crenata* BLUME ; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 15, figs. 42, 79.

1954. *Fagus crenata* BLUME ; TAKAHASHI, *Mem. Fac. Sci. Kyushu Univ.*, ser., D, vol. 5, no. 1, p. 56, pl. 3, figs. 7-12 ; pl. 4, figs. 1-8.

1961. *Fagus crenata* BLUME ; SUZUKI, *Sci. Rep. Fac. Art. Sci. Fukushima Univ.*, no. 10, p. 51, pl. 11, figs. 8-15.

1968. *Fagus crenata* BLUME ; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 47, pl. 3, figs. 1-4, 8 ; pl. 4, fig. 8 ; pl. 6, fig. 6.

1971. *Fagus crenata* BLUME ; OZAKI, *Sci. Rep. Yokohama Nat. Univ.*, Sec. 2, no. 18, pl. 8, figs. 9, 10, 12-14.

Description : Leaves variable in shape and size, ovate to oval in outline, 2 to 12 cm long and 1.2 to 7 cm wide ; apex acute, base slightly asymmetrical, obtuse and sometimes rather cordate ; margin undulate, few of them have minute teeth ; midvein prominent and stout near the base and tapered at apices, zigzag at the upper portion of blade ; secondary veins 5 to 13 pairs, subalternate, diverging from the midvein at angles of 40 to 50 degrees in middle portion, straight and subparallel, near marginal border abruptry curving up along the margin, or enterring into the marginal teeth, tertiaries percurrent ; quaternary veins orthogonal reticulate ; petiole short, 0.3 to 1 cm in length ; texture subcoriaceous.

Fruit ; Cupula 4 lobed, villous ; lobes with obtuse apex, 1.7 cm in length and 0.8 cm in width ; peduncle stout, 1.2 cm long ; nut ovate in outline, trigonal pyramid, acute at tip and truncate at base, 1.3 cm long and 1.7 cm wide.

Remarks : The present species composed by leaves, cupules and nuts and is the most abundant in the collection (occupied about 13% of the total number of specimens). They are identical with living *Fagus crenata* BLUME which is widely distributed from southern Hokkaido to Kyushu. It is a representative tree of the cool-temperate forests in Japan.

Collection : GSJ F7526, 8025, 8037, 8071, 8072.

Fagus japonica MAXIMOWICZ
Pl. 7, figs. 7-9

1888. *Fagus japonica* MAXIMOWICZ *fossils ;* NATHORST, *Pal. Abh.*, vol. 4, no. 3, p. 33, pl. 9, figs. 3, 5, 6, 8.

1940. *Fagus japonica* MAXIMOWICZ ; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p.

59, pl. 7, figs. 2, 3, 7, 14.

1940. *Fagus crenata* BLUME; ENDO, (part) *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, pl. 6, fig. 25.

1940. *Fagus japonica* MAXIMOWICZ; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 16, figs. 10, 20, 39, 46, 50, 51.

1940. *Fagus crenata* BLUME; KOIZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, fig. 38.

1961. *Fagus japonica* MAXIMOWICZ; SUZUKI, *Sci. Rep. Fac. Art. Sci. Fukushima Univ.*, no. 10, p. 53, pl. 12, figs. 1a-d, 2a-i.

1972. *Fagus japonica* MAXIMOWICZ; OZAKI, *Sci. Rep. Yokohama Nat. Univ.*, Sec. 2, no, 18, pl. 7, fig. 5.

Description : Leaves ovate to obovate and somewhat asymmetrical in general outline, 6 to 12 cm long and 2.6 to 6 cm wide, apex acute, base obtuse or sometimes rather cordate; margin crenate upper half of the blade and entire or undulate at the bottom, petiole stout, 0.4 to 1 cm long; primary vein stout and taper to a point; secondary veins 13 to 16 (rarely 10) pairs, diverging from the midvein at angles of about 50 degrees in middle part of blade, opposite or alternate, almost parallel each other, extending straight to near marginal border and abruptly curving up and each terminating near the next upper secondaries, camptodromous; tertiary veins regularly percurrent, fine spacing; quaternary veins obscure.

Fruit: Cupula with stalk, cup body oboid, 8 mm long, dehiscent into 4 valves; prickles rather coarsely and equally distributed from base to top, about 1 mm long; stalk narrow and more than 35 mm long, glabrous; seed oval and triangular, much longer than the cup body.

Remarks : The present species is one of the most dominant in the collection (about 11%), and is resembles to living *Fagus japonica* in foliar shape and venation character. The living species is growing in Honshu, Shikoku and Kyushu sparsely.

Collection : GSJ F8026, 8073, 8074.

Genus *Quercus* LINNAEUS

Quercus aliena BLUME

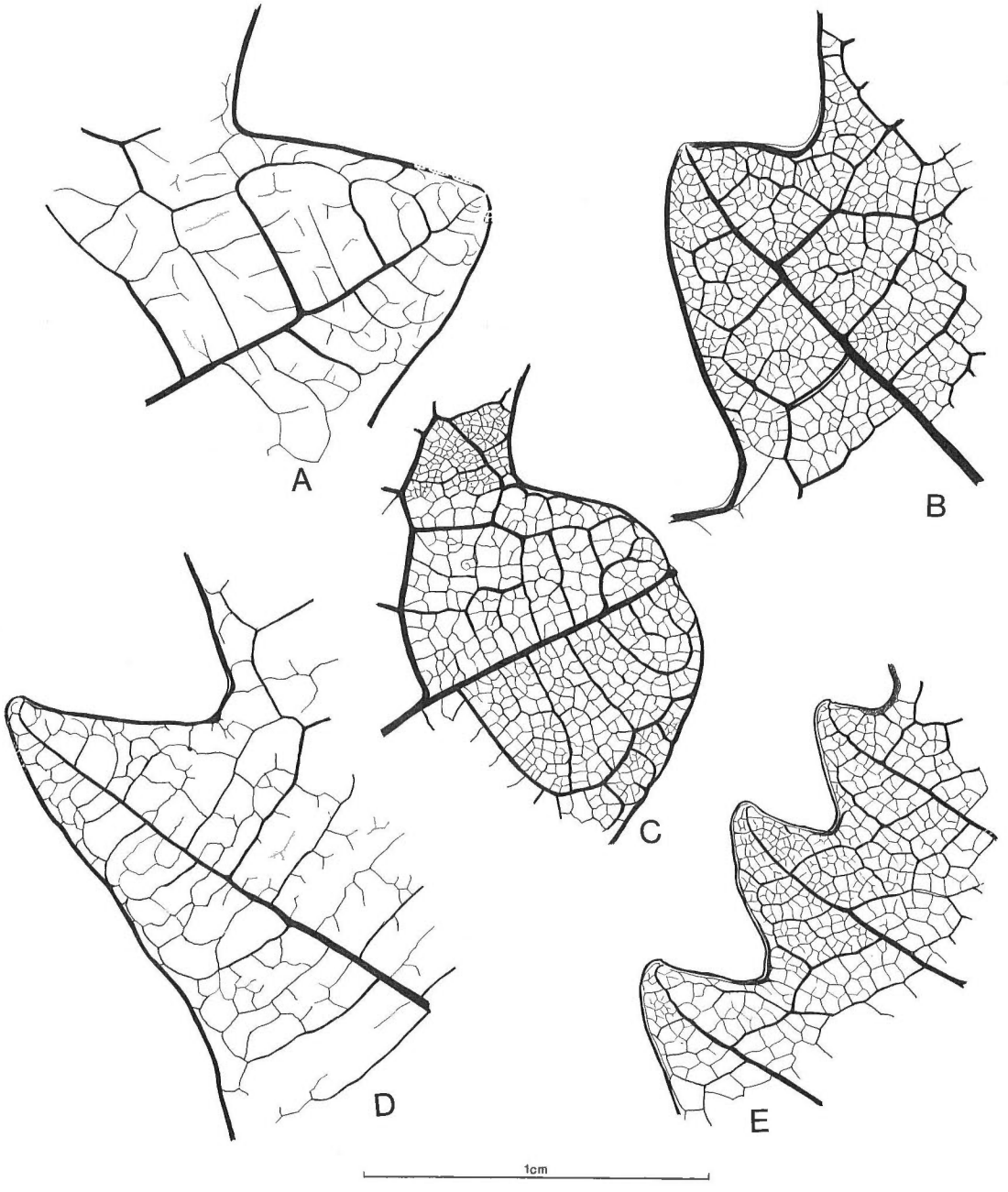
Pl. 7, fig. 10; text-figs. 5-A, 6

1961. *Quercus aliena* BLUME; SUZUKI, *Sci. Rep. Fac. Art. Sci. Fukushima Univ.*, no. 10, p. 55, pl. 12, figs. 3, 4.

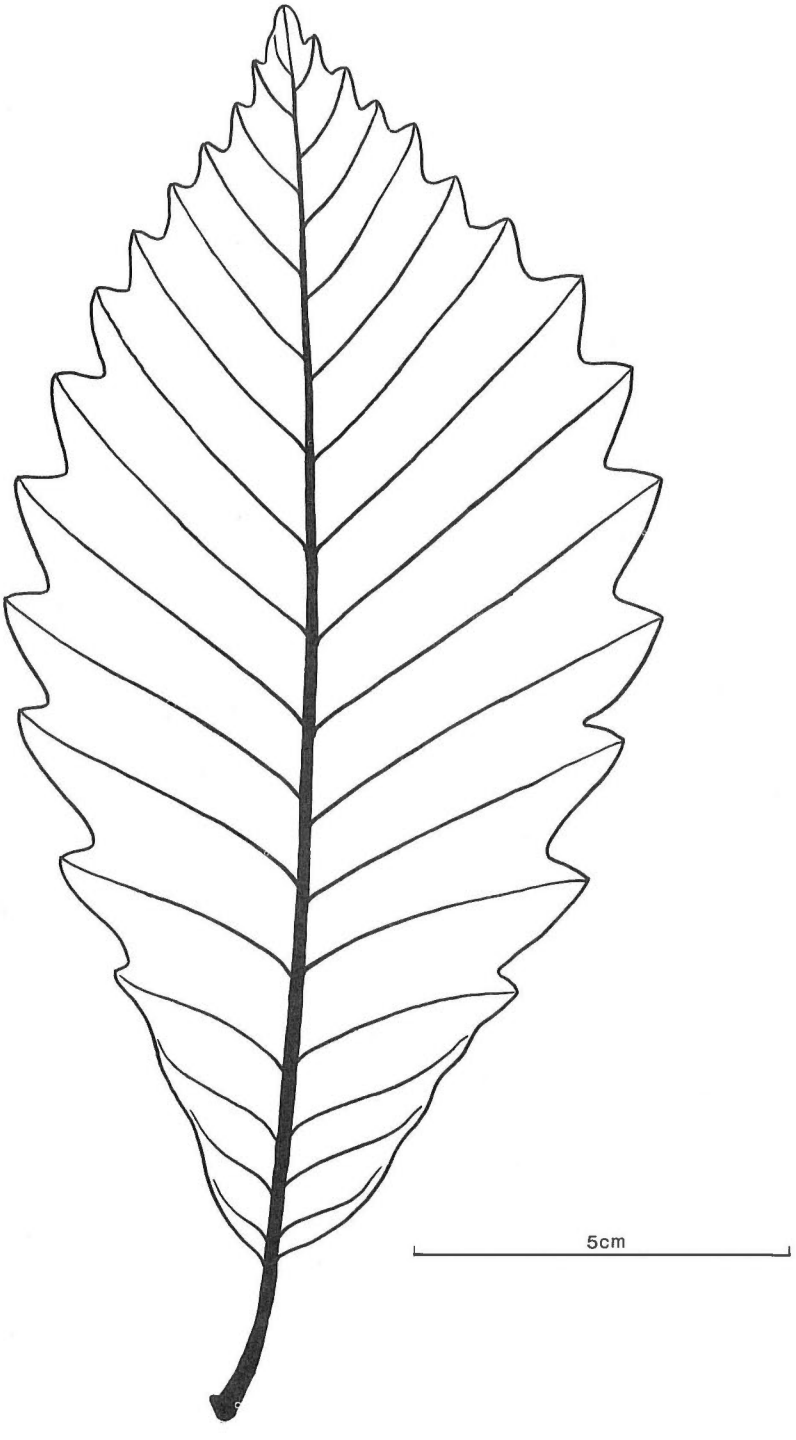
Description : Leaf large, about 17 cm (estimated) long and 9 cm (estimated) wide, apex and base missing, margin deeply undulate or lobed; marginal teeth large, straight to slightly convex on apical side and convex on basal side; primary vein strong; secondary veins strong, alternate to subopposite, neary parallel each other, about 16 pairs (estimated), diverging from the midvein at angles of 40 to 65 degrees, running almost straight to the marginal teeth; tertiary veins percurrent; quaternary veins obscure.

Remarks : A single incomplete leaf is fairly identical to some leaves of *Quercus* by the above-described characters. Among the extant species of *Quercus*, this specimen is similar in general outline to those of *Q. dentata* THUNBERG, *Q. mongolica* var. *grosseserrate* (BLUME) REHDER et WILSON and *Q. aliena* BLUME, and the most close resemblance is observed to the last species in marginal serration, the number of the secondary venation and especially feature of venation in the marginal teeth (text-fig. 5-A).

SUZUKI (1961) described the present species from the upper Miocene Fujitoge formation



Text-fig. 5 Venation characters of fossils and related extant species (All figures are ×5)
A. *Quercus aliena* BLUME. SFPG no. 13.
B. *Quercus aliena* BLUME. (Leaf of the extant species for comparison)
C. *Quercus dentata* THUNBERG. (Leaf of the extant species for comparison)
D. *Quercus mongolica* var. *grosseserrata* (BLUME) REHDER et WILSON. GSJ F8062.
E. *Quercus mongolica* var. *grosseserrata* (BLUME) REHDER et WILSON. (Leaf of the extant species for comparison)



Text-fig. 6 A restoration of *Quercus aliena* BLUME. SFPG no. 13. (Natural size)

and the Pliocene Izumi formation in Fukushima Prefecture, and it is identical with the present one.

Quercus aliena BLUME is mainly distributed in the cool- to warm-temperate zones of western Japan, Korea and China as well as in the Japan Sea side of northeast Honshu.

Collection : SFPG no. 13.

Quercus mongolica var. *grosseserrata* (BLUME) REHDER et WILSON

Pl. 8, figs. 2, 3; text-fig. 5-D

1888. *Quercus crispula* BLUME *fossilis*; NATHORST, *Pal. Abh.*, vol. 4, no. 3, p. 33, pl. 9, figs. 9, 10.

1940. *Quercus crispula* BLUME; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 60, pl. 6, fig. 1; pl. 10, fig. 7.

1940. *Quercus crispula* BLUME; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 16, fig. 13.

1940. *Quercus grosseserrata* BLUME; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 16, figs. 43, 47, 75.

1968. *Quercus crispula* BLUME; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 49, pl. 4, figs. 3, 4, 6.

1981. *Quercus mongolica* var. *grosseserrata* (BLUME) REHDER et WILSON; KAMATA and al., *Jour. Nagasaki Earth Sci. Assoc.*, no. 33-34, p. 19, pl. 3, fig. 5.

Description : Leaves obovate, 7 to 15 cm long and 3 to 7 cm wide; acute or abruptly cuneate at the apex and auriculate at the base; margin coarsely serrate to undulately dentate most of the teeth are single but a few of them are double; marginal teeth large, slightly convex to concave on apical side and apparently convex on basal side with slightly curving up acute apex; primary vein strong, straight to curving gently; secondary veins strong, nearly parallel each other, 12 to 15 pairs, diverging from the midvein at angles of 40 to 50 degrees, running almost straight to the marginal teeth except basal one or two secondaries which form loops at margin; tertiary veins percurrent; petiole stout and thick.

Fruit; Nuts ovoid, gradually narrowed and rounded at apex, 1.9 cm long and 1.2 cm in diameter.

Remarks : The present species is characterized by large acute serrations on the margins and auriculate base. These characters are identical with the living *Quercus mongolica* var. *grosseserrata* (BLUME) REHDER et WILSON.

KOIDZUMI (1940) discriminated between *Quercus crispula* BLUME (this species name is the synonym of *Q. mongolica* var. *grosseserrata* (BLUME) REHDER et WILSON) and *Q. grosseserrata* BLUME by the shape of their marginal teeth. He pointed out that *Q. grosseserrata* had single serration and *Q. crispula* had double ones on their leaves respectively. The recent *Q. mongolica* var. *grosseserrata* has, however, both types of serration on its leaves, though the single serration leaves are predominant in number than the double serration ones, and they may be included into the variation of the present species.

The present species is now flourished in the Japanese Islands and is a representative tree in the cool-temperate zone of Japan, as well as the beech, *Fagus crenata* BLUME.

Collection : SFPG no. 33, GSJ F7545, 8062.

Quercus serrata THUNBERG
Pl. 8, fig. 1

1933. *Quercus serrata* THUNBERG; MIKI, *Bot. Mag.*, vol. 47, no. 561, p. 623, figs. 1 E-H.
1940. *Quercus serrata* THUNBERG; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 16, fig. 59.
1968. *Quercus serrata* THUNBERG; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 49, pl. 3, fig. 6a; pl. 4, fig. 2.
1971. *Quercus serrata* THUNBERG; SUZUKI and NAKAGAWA, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 42, no. 2, p. 197, pl. 28, figs. 1-7.
1971. *Quercus serrata* THUNBERG; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 26, pl. 5, figs. 2, 3.

Remarks : Incomplete 31 specimens are referable to *Quercus serrata* THUNBERG by their obovate outline, acute to sickle-shaped teeth with callous tips and acute at apex. The present species is common in the coll- to warm-temperate zones of Japan and Korea.

Collection : SFPG no. 61.

Family Ulmaceae

Genus *Celtis* LINNAEUS

Celtis jessoensis KOIDZUMI
Pl. 8, fig. 5

1940. *Celtis jessoensis* KOIDZUMI; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 16, fig. 12.
1940. *Celtis bungeana* var. *jessoensis* KUDO; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 60, pl. 8, figs. 15, 23.

Remarks : The present specimens, consisting of many well preserved leaves, are referred to *Celtis jessoensis* KOIDZUMI in the ovate foliar shape and small number of the secondary veins, and the marginal character of coarsely and regularly serrate on the upper two-third to four-fifth portion and entire on basal portion of the blade.

Celtis bungeana var. *jessoensis,* described by ENDO (1940) from the Shiobara fossil flora, is synonymous with the present species.

This modern species grows now in the cool-temperate zone from Hokkaido to Kyushu, Japan and Korea, and luxuriant growth is almost between 800 and 1,300 m above sea level in central Honshu.

Collection : GSJ F8027.

Genus *Ulmus* LINNAEUS

Ulmus davidiana var. *japonica* (REHDER) NAKAI
Pl. 8, figs. 6, 7

1940. *Ulmus japonica* SARGENT; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 61, pl. 6, fig. 22, pl. 7, fig. 16.
1940. *Ulmus propinqua* KOIDZUMI; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 17, fig. 54.

Remarks : A large number of leaf impressions and a samara were examined. The leaves are characterized by their obovate foliar shape, obliquely cuneate to obtuse base and

dichotomously branching secondaries. The examined specimens all belong to *Ulmus davidiana* var. *japonica* (REHDER) NAKAI (Syn. *U. japonica* SARGENT and *U. propinqua* KOIDZUMI), Which is growing in the cool-temperate zone of Hokkaido, Honshu, Shikoku and Kyushu, Japan, and extends to Korea and China.

Collection : SFPG no. 34, GSJ F8028.

Ulmus laciniata (TRAUTVETTER) MAYR
Pl. 8, fig. 4

Description : Leaf large, obovate, 13 cm long and 9.6 cm wide, widest in the one-third portion from the tip; apex broadly rounded with short acuminate tips, base asymmetrically cordate to obtuse; four acuminate lobes extending on the upper part of the blade; midrib stout, nearly straight, gradually slender toward the apex; secondary veins 14 pairs, opposite to alternate, leaving the midrib the angles of 50 to 60 degrees near the base, about 30 degrees above, craspedodromous, running into larger teeth; tertiary veins thin, percurrent; margin duplicately serrulated with acute teeth; petiole thick, short.

Remarks : The present specimens consist of only one almost complete leaf and two fragments. They are characterized by four caudal lobes extending on the upper part of the blade, dichotomously branching secondary venation and oblique base. These characters resemble the leaves of *Ulmus laciniata* (TRAUTVETTER) MAYR, which is now widely distributed in the cool-temperate zone of Japan, north China and Siberia.

Collection : SFPG no. 19.

Family Moraceae

Genus *Cudrania* TRECUL

Cudrania tricuspidata (CARRIERE) BUREAU
Pl. 9, figs. 1, 2; text-fig. 7

Description : Leaves variable in shape, generally broadly obovate or oval and sometimes trilobed. 3.5 to 7 cm long and 3.1 to 4.6 cm wide; apex apparently abruptly acute; base rounded to broadly obtuse; midvein rather stout, nearly straight; secondary veins 3 to 4 pairs, opposite to subopposite, variable as to spacing and angle of divergence, curved abruptly and joining superadjacent secondary at acute angle; tertiary and quaternary veins obscure; margin entire; petiole normal, about 1 cm long; texture firm.

Remarks : The present species, represented by several leaves, is characterized by leaf form and secondary venation as described above, and is probably included in the living *Cudrania tricuspidata* in the warm-temperate zone of Korea and China.

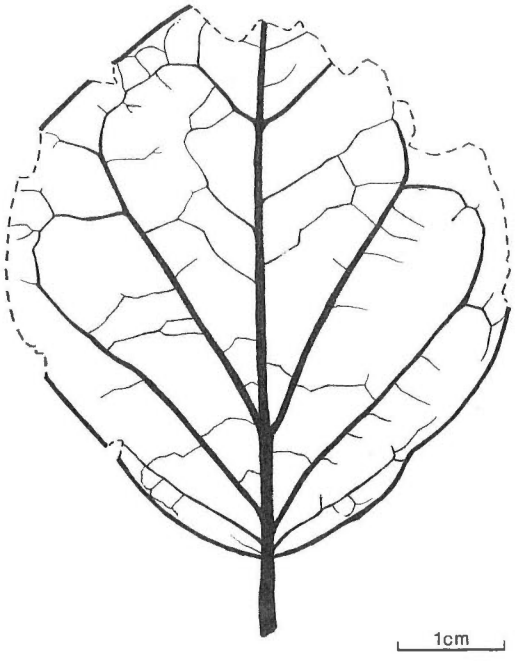
The occurrence of leaves of this exotic species is the first record of a fossil in Japan.

Collection : SFPG no. 146, GSJ F8038.

Genus *Morus* LINNAEUS

Morus bombycis KOIDZUMI
Pl. 9, fig. 4

Description : Leaf cordate in general outline, obliquely three lobed; deeply cordate at



Text-fig. 7 Venation characters of fossil *Cudrania tricuspidata* (CARRIERE) BUREAU. SFPG no. 146, ×1.4.

base and acute at apex; 10 cm long (estimated) and 7.3 cm wide; margin coarsely serrate except basal part and sinuses; venation infrabasal imperfect acrodromous, midrib moderate, slightly curved, tapered apically; lateral primary veins craspedodromous; secondary veins leaving the midrib, 3 pairs rather slender; tertiary veins obscure; texture thin; petiole stout, 2 cm long.

Remarks: The present species is based on a single leaf impression. It is referred to *Morus bombycis* KOIDZUMI by its obliquely three lobed foliar shape, coarsely serrate margin and venation characters described above. The living species is widely distributed in the coll- to warm-temperate and subtropical regions of Asia.

Collection: SFPG no. 62.

Family Urticaceae

Genus *Boehmeria* JACQUIN

Boehmeria tricuspis (HANCE) MAKINO

Pl. 9, figs. 5, 6

Description: Leaves orbicular in general outline, 6.5 cm long and 5.5 to 5.8 cm wide; base widely cuneate; apex more or less 3-lobed with acute tip; margin coasely serrate with acute tip, straight or rather concave at apical side and convex at basal side of teeth, sinus acute; venation acrodromous, midvein moderate, lateral primaries making angles of 30 to 45 degrees with the midvein, curving up and making loops, texture membranaceous; petiole more than 1 cm long.

Remarks: Only two almost complete leaf impressions are closely similar to the living

Boehmeria tricuspis (HANCE) MAKINO by the orbicular foliar shape, trinerved primaries and coarsely serrate margin. This perennial herb is now widely distributed in the cool- to warm-temperate zones from Hokkaido to Kyushu, Japan.

Collection : SFPG nos. 122, 187.

Family Polygonaceae

Genus *Polygonum* LINNAEUS

Polygonum cuspidatum SIEBOLD et ZUCCARINI

Pl. 9, fig. 7

Description : Leaf oval in general outline, 6 cm long (estimated) and 4.2 cm wide; apex missing, base truncate; margin entire or somewhat undulate; primary vein straight, tapering at apice; secondary veins 4 pairs, alternate, camptodromous, diverging from the primary vein at angles of 50 to 60 degrees, extending slightly curving up, joining with the branches of superadjacent secondary veins, looping well within the margin; intersecondary veins composite; tertiary veins random angular mesh, texture coriaceous; petiole 1.5 cm long.

Remarks : Though small in size, the present leaf specimen is referred to *Polygonum cuspidatum* SIEBOLD et ZUCCARINI by its venation characters, truncate base and undulate margin. This perennial grass is widely distributed in the cool- to warm-temperate zones of Japan, Formosa, Korea and China.

Collection : SFPG no. 113.

Family Magnoliaceae

Genus *Magnolia* LINNAEUS

Magnolia obovata THUNBERG

Pl. 10, fig. 1

1937. *Magnolia obovata* THUNBERG; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 315, fig. 4-A.

1938. *Magnolia obovata* THUNBERG; MIKI, *Jap. Jour. Bot.*, vol. 9, fig. 14-Da.

1940. *Magnolia obovata* THUNBERG; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 63, pl. 12, fig. 3.

1941. *Magnolia obovata* THUNBERG; MIKI, *Jap. Jour. Bot.*, vol. 11, p. 274, fig. 13-A.

1962. *Magnolia obovata* THUNBERG; MIKI and KOKAWA, *Jour. Bot. Osaka City Univ.*, vol. 13, p. 77, pl. 10, fig. H.

1968. *Magnolia obovata* THUNBERG; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 50, pl. 8, fig. 3.

Remarks : Large number of leaf impressions comprising some complete ones were examined. The present species is characterized by large size, elliptical outline, entire margin, rounded to obtuse base and mucronately acute apex. It is identical to the living *Magnolia obovata* THUNBERG.

This Japanese cucumber tree is common in the cool- to warm-temperate zones of Japan and China.

MIKI (1937, 1938, 1941, 1962) described many seed remains of the present species from the Pliocene and Pleistocene sediments in various localities of Honshu and Kyushu. A leaf impression of the present species was described from the Pliocene Minoshirotori flora in

Fukui Prefecture by MATSUO (1968) and it is identical with the examined species.

Collection : GSJ F7544.

Family Lauraceae

Genus *Lindera* THUNBERG

Lindera membranacea MAXIMOWICZ

Pl. 10. fig. 2

Description : Leaf elliptically obovate, 11.3 cm long and 6 cm wide (estimated); obtuse with cuspidate at apex, broadly acute at base; midrib stout, almost straight; 9 pairs of secondary veins irregularly spaced, diverging at angles of 30 to 50 degrees, commonly forking near the margin, camptodromous; tertiary veins thin; margin entire; petiole stout, more than 3 mm long.

Remarks : A single leaf, lacking in its one-forth of left side, is closely similar to the extant *Lindera membranacea* MAXIMOWICZ in the characters mentioned above. The living species is growing in the cool- to warm-temperate zones of Hokkaido and Honshu, principally on the Japan Sea side of Honshu.

Collection : SFPG no. 116.

Lindera obtusiloba BLUME

Pl. 10, fig. 3

Description : Leaves orbicular in general outline, normally three lobed, 3.5 to 11.5 cm long, 2.6 to 11.5 cm wide; apex acute with round tip, base round or cuneate; petiole stout, curving, 0.7 to 1.9 cm long; venation infrabasal imperfect acrodromous, midrib slender, separating just below the base of lamina, the laterals diverging at angles of 30 to 40 degrees, curving upward; 3 or 5 secondaries branching abaxially and forming marked loops within the margin; tertiaries forming a coarsely random network, within which the nervilles a finely reticulate areolation; margin entire.

Remarks : Thirty five leaf specimens were examined. This species is characterized by their orbicular foliar shape, most of leaves divided into three lobes near the apex and infrabasal acrodromous venation character. The examined leaves are variable in shape, but fall within the limits of variation of the modern species *Lindera obtusiloba* BLUME.

The living species is widely distributed in the cool- to warm-temperate zones of Japan, Korea and eastern part of continental China.

Collection : GSJ F8029.

Lindera umbellata THUNBERG

Pl. 10, fig. 4

1941. *Benzoin umbellatum* REHDER; MIKI, *Jap. Jour. Bot.,* vol. 11, p. 274, figs. 13 I-K.

1971. *Benzoin umbellatum* REHDER; ONOE, *Rep. Geol. Surv. Jap.,* no. 241, p. 28, pl. 5, figs. 7-9.

Remarks : The present species is based on three almost complete leaf impressions which are simlar to the living *Lindera umbellata* THUNBERG in elliptical foliar shape, attenuate

base and acuminate apex.

MIKI (1941) reported some leaf and seed remains under the name of *Benzoin umbellatum* REHDER (Syn. *Lindera umbellata* THUNBERG) from the lower Pliocene *Pinus trifolia* beds in Aichi Prefecture. Some leaf impressions of *Benzoin umbellatum* from an interglacial age of Pleistocene Ebino flora, Miyazaki Prefecture by ONOE (1971). They are similar to the present species. The living spicebush is native of Japan and continental China.

Collection : SFPG no. 66.

Genus *Parabenzoin* NAKAI

Parabenzoin praecox (SIEBOLD et ZUCCARINI) NAKAI
Pl. 10, fig. 5

Description : Leaves oval to elliptical in general outline, acuminate at apex and acute at base, 5.8 to 6 cm long and 3.2 to 3.4 cm wide; margin entire; primary vein slender, almost straight; 5 pairs of secondaries alternate, diverging at angles of 30 degrees at basal part and 50 degrees at upper part of the blade, gently curving up and joining superadjacent veins and making loops; tertiary veins obscure; petiole somewhat curved, 1.8 cm long.

Remarks : A few but complete leaves were examined. The present species is characterized by broadly ovate in foliar shape, acuminate apex, acute base and long petiole, and is identical to *Parabenzoin praecox* (SIEBOLD et ZUCCARINI) NAKAI.

This deciduous shrub is endemic to Japan and very common on such mesic sites as mountain-streambanks in the cool- to warm-temperate zones of Honshu, Shikoku and Kyushu, Japan.

Collection : SFPG no. 49.

Family Trochodendraceae

Genus *Trochodendron* SIEBOLD et ZUCCARINI

Trochodendron aralioides SIEBOLD et ZUCCARINI
Pl. 10, figs. 6, 7

1940. *Amelanchier asiatica* ENDLICHER; ENDO, (part) *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 64, pl. 8, fig. 10.

Description : Leaves very variable in general outline, broadly obovate; acuminate or apparently abruptly cuneate at apex and cuneate to round at base; 2.8 to 12 cm long and 1.2 to 5 cm wide; primary vein stout, almost straight, tapering at apice; secondary veins thin, 6 to 10 alternate pairs, diverging from the primary at angles of about 20 degrees, extend straightly near the margin and make loops; tertiary veins orthogonal reticulate; petiole stout, 2 to 6.5 cm long; texure coriaceous.

Fruits subglobose, depressed at apex and obtuse to cuneate at base, 6 to 8 mm in diameter, stems 1.4 to 3.6 cm long, clustered with six fruits.

Remarks : Many well preserved leaves and some clustered fruits are obtained. These leaf specimens are variable in size and leaf forms, but fall within the variation displayed by the living *Trochodendron aralioides* SIEBOLD et ZUCCARINI.

Fruits figured as *Amelanchier asiatica* ENDLICHER by ENDO (1940, pl. 8, fig. 10) was

misjudged. The clustered fruits are identical with those of the present species.

This evergreen tree is nearly restricted to the cool- to warm-temperate zones of the central Honshu through Shikoku, Kyushu, Ryukyu to Formosa.

Collection : IGPS Reg. no. 40694, SFPG no. 63.

Trochodendron aralioides var. *longifolium*

(MAXIMOWICZ) OHWI

Pl. 11, fig. 1

1940. *Trochodendron aralioides* var. *longifolium* (MAXIMOWICZ) OHWI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 61, pl. 9, fig. 4.

Remarks : The present specimens are characterized by their oblong-lanceolate leaves, acuminate base, acute apex, long petiole, slender secondary venation and crenate or serrulate marginal serration on upper half of the blade. The examined specimens are identical with the existing *Trochodendron aralioides* var. *longifolium* (MAXIMOWICZ) OHWI, which is growing in the cool- to warm-temperate zones of Japan together with *Trochodendron aralioides* SIEBOLD et ZUCCARINI.

Collection : YNU 31391.

Family Eupteleaceae

Genus *Euptelea* SIEBOLD et ZUCCARINI

Euptelea polyandra SIEBOLD et ZUCCARINI

Pl. 11, figs. 2, 3

Description : Leaves trianguloid to ovate, 4.7 to 10 cm (estimated) long and 3.3 to 8 cm (estimated) wide; abruptly cuneate at apex, broadly acute to truncate at base and decurrent on the petioles; margin dentate to serrate; each teeth triangular with incurved apex; primary vein medium, almost straight; secondary veins 5 to 7 pairs, subopposite to alternate, diverging at various angles ranging from 30 to 45 degrees, craspedodromous; tertiary veins irregularly percurrent; petiole more than 1.7 cm.

Samara obovate in general outline, 1.4 cm long and 4 mm wide, rounded at apex and decurrent at base; seed oblong, 2 mm long and 1 mm wide.

Remarks : The present species is based on a small but nearly complete leaf, two incomplete leaves and a samara. These specimens are closely similar to the modern *Euptelea polyandra* SIEBOLD et ZUCCARINI in the characters mentioned above.

This deciduous tree is abundant along mountain streams in the coll- to warm-temperate zones of Honshu, Shikoku and Kyushu, Japan.

Collection : GSJ F8075, 8076.

Family Cercidiphyllaceae

Genus *Cercidiphyllum* SIEBOLD et ZUCCARINI

Cercidiphyllum japonicum SIEBOLD et ZUCCARINI

Pl. 11, figs. 4, 5

1888. *Cercidiphyllum japonicum* SIEBOLD et ZUCCARINI *fossile*; NATHORST, *Pal. Abh.*, vol. 4,

no. 3, p. 34, pl. 9, figs. 16, 17; pl. 10, fig. 10.

1940. *Cercidiphyllum japonicum* SIEBOLD et ZUCCARINI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 62, pl. 8, figs. 2, 6.

1940. *Cercidiphyllum japonicum* SIEBOLD et ZUCCARINI; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 17, fig. 87.

Description : Follicle cylindrically lorate, slightly curved; cuneate at base and mucronate at apex; 15 mm long and 4 mm wide.

Remarks : The genus *Cercidiphyllum* was widely distributed in the northern hemisphere during upper Cretaceous and Tertiary periods, but recently it is known only from East Asia. This species is one of the most common collection in this flora. These materials, based on well preserved leaves, follicles and seeds, are identical to the modern *Cercidiphyllum japonicum* SIEBOLD et ZUCCARINI. The living species is widely growing in the cool- to warm-temperate zones of the Japanese Archipelago.

Collection : SFPG no. 189, GSJ F8030.

Cercidiphyllum magnificum (NAKAI) NAKAI
Pl. 11, fig. 6

Description : Leaves reniform, retuse or round at apex, cordate at base, 3.5 to 4.5 cm long and 4.5 to 5.7 cm wide; margin crenate-serrate, slightly upcurved and glandular teeth; venation palmately 5 to 7-nerved, the midvein medium, running zigzag in its upper half, the upper pair of lateral primaries divergent at angles of 45 to 50 degrees, curving up and make loops near the margin, the lower pair of lateral nerves broadly curving; secondary veins on midrib and lateral primaries 3 pairs each, looping well within the margin; tertiary and quaternary veins obscure; petiole missing.

Remarks : The present species is represented by a few well preserved leaves. It is identical to the genus *Cercidiphyllum*, and especially *C. magnificum* (NAKAI) NAKAI in their reniformed outline and rounded or retused apex.

This species of deciduous tree is restrictedly distributed in the cool-temperate zone of central to northern Honshu, Japan.

Collection : SFPG no. 125.

Family Ranunculaceae

Genus *Clematis* LINNAEUS

Clematis apiifolia DE CANDOLLE
Pl. 11, fig. 7

1955. *Clematis apiifolia* DE CANDOLLE; ENDO, *Sangyo Tosho*, pl. 43, fig. 2.

Description : Leaflets broadly ovate in general outline, generally palmately three-lobed, the base broadly rounded, acute at apex of central lobe, lateral lobes short, directed upward, with acute tips, sinuses acute, length 4.2 to 5.6 cm, width 3.5 to 5 cm; primary vein trinerved separating just above the base of lamina, midvein extending slightly curved; lateral primaries making at angles with the midvein about 25 degrees in the base then turning up and connect with the secondary veins from midrib; secondary veins from lateral primaries semicraspedodromous; tertiary veins missing.

Remarks : A few leaflet materials were examined. They are identical with *Clematis apiifolia* DE CANDOLLE by the characters described above. The modern species is widely distributed in the cool- to warm-temperate zones of Honshu, Shikoku and Kyushu, Japan.

ENDO (1955) figured a complete leaf specimen of this species from the Shiobara fossil flora without any description.

Collection : SFPG no. 65.

Clematis apiifolia var. *biternata* MAKINO
Pl. 11, fig. 8

Description : Leaflet lanceolate, 5.9 cm long and 2 cm wide, apex elongate-acuminate, base obtuse; margin remotely and irregularly dentate; venation acrodromous, midvein weak, almost straight, lateral primaries leaving slightly above the base, running upward and connect with the secondaries from the midvein at the middle part of the blade and making loops to the tip.

Remarks : The present species is based on a single almost complete leaflet. It is referable to *Clematis apiifolia* var. *biternata* MAKINO by the lanceolate foliar shape and coarsely remotely dentate margin. This deciduous liane is mainly distributed in the cool-temperate zone of the mountain region of Kanto district, Japan.

The present species is the new fossil record from the Shiobara fossil flora.

Collection : SFPG no. 131.

Family Berberidaceae

Genus *Berberis* LINNAEUS

Berberis amurensis var. *japonica* (REGEL) REHDER
Pl. 11, fig. 9

Description : Leaf obovate, 4 cm long and 1.8 cm wide, apex rounded, base cuneate; margin serrulate with hairly tips; primary vein moderate, sinuous in the middle to the upper part, secondary vein sinuous, lower secondaries diverging from midvein more acute than upper half, making angular loops near the margin.

Remarks : A single almost complete leaf is examined. It has obovate foliar shape, round apex, acuminate base and serrate marginal teeth with hairly tip. The present species is referable to *Berberis amurensis* var. *japonica* (REGEL) REHDER.

This deciduous small tree is widely distributed in the cool-temperate zone from Hokkaido to Kyushu, Japan and extends to Korea and China.

Collection : SFPG no. 134.

Family Ceratophyllaceae

Genus *Ceratophyllum* LINNAEUS

Ceratophyllum demersum LINNAEUS
Pl. 12, figs. 4, 5

1940. *Ceratophyllum demersum* LINNAEUS; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1. p. 17, figs. 56, 69.

1961. *Ceratophyllum demersum* LINNAEUS; MIKI, *Jour. Bio.* no. 12, p. 111 pl. 2, N; fig. 6.
1965. *Ceratophyllum demersum* LINNAEUS; SUZUKI and SOHMA, *Sci. Rep. Tohoku Univ.*, 4th ser., vol. 31, no. 3, pl. 2, fig. 18.

Description: Leaves verticillate arrangement, dicotomously branching once or twice, linear with several prickles on it. 10 to 12 mm long.

Nuts oval, 4 mm long and 3 mm wide; three spines fine, slightly curved, 7 to 11 mm long.

Remarks: A lot of leafy stems and a leafy stem with two nuts were examined. The present species is referred to the cosmopolitan modern species *Ceratophyllum demersum* LINNAEUS in the above described characters.

MIKI (1961) described many fruit remains of the species from various localities of Pliocene and Pleistocene formations in Japan and they are identical to the author's collection.

Collection: GSJ F8031.

Family Actinidiaceae

Genus *Actinidia* LINDLEY

Actinidia arguta (SIEBOLD et ZUCCARINI) PLANCHON ex MIQUEL

Pl. 11, fig. 11

Description: Leaves oval, 4 to 9.5 cm long and 3 to 6.5 cm wide; apex rounded with cuspidate; base rounded or slightly cordate; margin singly or doubly serrulate with attenuate teeth; midvein straight or slightly sinuous; secondary veins 4 to 6 pairs, diverging from the midvein at angles of 40 to 60 degrees in basal part and about 30 degrees in the middle to the upper part, gently curving up, forming marginal loops with tertiary veins; tertiary veins percurrent in intercostal area, quaternary veins orthogonal reticulate; ultimate veinlets once or twice branched; petiole bending near the base, more than 5 cm long.

Remarks: Several well preserved leaf impressions have been obtained. These specimens are characterized by oval foliar shape, long petiole and especially marginal serration character described above. The examined species is referable to *Actinidia arguta* (SIEBOLD et ZUCCARINI) PLANCHON ex MIQUEL, which is growing in the cool- to warm-temperate zones of Japan, Korea, China and Sakhalin.

Collection: GSJ F8032.

Actinidia polygama (SIEBOLD et ZUCCARINI) MAXIMOWICZ

Pl. 11, fig. 10

Description: Leaves ovate to broadly ovate in general outline, 4.7 to 5.8 cm long and 2.4 to 4.4 cm wide; mucronate to acuminate at apex, rounded at base; primary veins medium, mostly straight or slightly curved; seconday veins camptodromous, 4 to 6 subopposite pairs, diverging from the midvein at angles of about 60 degrees in basal part and about 30 degrees in the middle to the upper part, extending gently curving up and making loops; tertiary veins in intercostal area percurrent, in marginal area extending from the corner of the secondary's arche to the margin; quaternary veins orthogonal reticulate; ultimate veinlets once or twice

brached; margin irregularly spaced serrate with gland-like tips; petiole stout, more than 1 cm long.

Remarks : The present species is represented by three leaf impressions and are closely similar to those of *Actinidia polygama* (SIEBOLD et ZUCCARINI) MAXIMOWICZ by their venation and marginal characters mentioned above. This modern deciduous vine is widely distributed in the cool- to warm-temperate zones of Japan, Korea, China and Sakhalin.

Collection : SFPG no. 120.

Family Theaceae

Genus *Stewartia* LINNAEUS

Stewartia pseudo-camellia MAXIMOWICZ
pl. 12, fig. 1

1888. *Actinidiophyllum* sp.; NATHORST, *Pal. Abh.*, vol. 4, no. 3, p. 34, pl. 10, fig. 12.

1940. *Stewartia pseudo-camellia* MAXIMOWICZ; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 69, pl. 10, figs. 4, 14.

1940. *Stewartia pseudo-camellia* MAXIMOWICZ; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 22.

Remarks : These specimens are one of the most common fossils in the Shiobara fossil flora. They are variable in shape and size, but fall within the variation displayed by those of the living *Stewartia pseudo-camellia* MAXIMOWICZ.

The modern species now flourishes in central and southern Japan, especially common in the deep mountains of the cool-temperate zone.

ENDO (1940) and KOIDZUMI (1940) described leaves of the present species from the Shiobara fossil flora.

A fragmentary leaf specimen, lacking one third of basal part were reported by NATHORST (1888, pl. 10, fig. 12) under the name of *Actinidiophyllum* sp., is similar to the present species.

Collection : GSJ F7542.

Family Hamamelidaceae

Genus *Corylopsis* SIEBOLD et ZUCCARINI

Corylopsis gotoana MAKINO
Pl. 13, fig. 1

Description : Leaves asymmetrical oval in general outline, acute at apex, cordate at base, 6 to 9 cm long and 4.8 to 6 cm wide; venation palmately 7-nerved, radiate from the base; the lower lateral pair slender, diverging at angles from the midrib 90 to 100 degrees; the next lateral pair slender, diverging at angles of 60 to 80 degrees; the upper lateral pair medium, diverging at angles of 30 to 40 degrees; each laterals have 3 to 7 pairs secondary veins; midvein moderate, almost straight, 8 to 9 pairs secondaries alternate; tertiary veins fine spaced percurrent; quaternary veins and ultimate veinlets obscure; petiole stout, 1.5 to 2.2 cm long; margin remotely denticulate with shallowly obtuse or rounded sinus.

Remarks : The present species is represented by a lot of leaf materials, and are quite identical to the living *Corylopsis gotoana* MAKINO by their venation and marginal features.

This deciduous shrub is growing in the cool- to warm-temperate zones of central Honshu and westward in Japan.

Collection : SFPG no. 46.

Genus *Hamamelis* LINNAEUS

Hamamelis japonica SIEBOLD et ZUCCARINI

Pl. 13, figs. 2, 3

1940. *Hamamelis japonica* SIEBOLD et ZUCCARINI ; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 64, pl. 9, fig. 10.

1965. *Hamamelis japonica* SIEBOLD et ZUCCARINI ; SUZUKI and SOHMA, *Sci. Rep. Tohoku Univ.*, 4th ser., vol. 31, no. 3, pl. 2, figs. 12-14.

1971. *Hamamelis japonica* SIEBOLD et ZUCCARINI ; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 30. pl. 6, figs. 7-9.

Remarks : Several well preserved leaves were examined. The present species is characterized by rhombic foliar shape and undulate-toothed margin on the upper half of blade. The examined specimens are identical with the modern species of *Hamamelis japonica* SIEBOLD et ZUCCARINI, which is common in mountainlands of the cool- to warm-temperate zones in Japan.

A single specimen with two capsules is also identical to the genus *Hamamelis,* and is probably included in this species.

Collection : SFPG no. 185, GSJ F8034.

Hamamelis japonica var. *obtusata* MATSUMURA

Pl. 13, fig. 5

Description : Leaves asymmetrical rhomboid, obtuse or retuse at apex, obliquely rounded or slighly cordate at base ; 6.7 to 8.3 cm long, 6.5 to 8.4 cm wide ; margin undulate on the upper half of the blade ; primary vein stout, somewhat zigzag ; secondary veins in about 7 alternate pairs, diverging from the primary vein at angles of 30 to 50 degrees, craspedodromous ; tertiary veins orthogonal reticulate ; quaternary veins polygonal mesh ; ultimate veinlets obscure, more than once branching ; petiole stout, 5 to 10 mm long.

Remarks : A few but almost complete leaf impressions are examined. They are similar to the foliage of the modern *Hamamelis japonica* var. *obtusata* MATSUMURA in their asymmetrically rhombic shape, obtuse or slightly retused apex. One of the leaf impression illustrated by ENDO (1940, pl. 9, fig. 2) may fall within the variation displayed by the present species. This deciduous tree is growing in the cool-temperate zone of southern Hokkaido and on the Japan-Sea side of Honshu.

Collection : SFPG no. 72.

Hamamelis megalophylla KOIDZUMI

Pl. 13, fig. 6

1940. *Hamamelis megalophylla* KOIDZUMI ; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 18, fig. 17.

Remarks : A few but almost complete leaves were examined. The present specimens are characterized by the following features: large size (11 cm long, 8.5 cm wide), obliquely rhomboid in general outline, acute apex, rather asymmetrical cordate base, undulate margin on the upper half of lamina. These characters are referred to the living *Hamamelis megalophylla*. This deciduous tree of the modern species is restrictedly distributed in the cool-temperate zone of the Pacific Ocean side of Honshu, Japan.

Collection : SFPG no. 73.

Family Saxifragaceae

Genus *Cardiandra* SIEBOLD et ZUCCARINI

Cardiandra alternifolia SIEBOLD et ZUCCARINI

Pl. 13, fig. 8

Description : Leaf elliptical, 9.5 cm long (estimated) and 4.1 cm wide; margin coarsely serrate, marginal teeth triangular, convex or straight on the apical side and convex to concave on the basal side with outcurved acute tips; venation brochidodromous, midvein stout slightly curved, secondary veins making angles of 35 to 45 degrees with the midvein, curving up and joining tertiary veins or branches from the superajacent secondaries to form the marginal loops; tertiary veins in the intercostal area percurrent, while the tertiaries in the marginal area extending from the marginal loops of the secondaries and entering the marginal teeth; texture thin.

Remarks : The present species is based on a single leaf, though lacking in its apex and base. It is similar to the extant *Cardiandra alternifolia* SIEBOLD et ZUCCARINI in its venation characters and marginal serration form.

This perennial grass is growing in the warm-temperate zone of Honshu, Shikoku and Kyushu, Japan.

Collection : SFPG no. 128.

Genus *Deutzia* THUNBERG

Deutzia scabra THUNBERG

Pl. 12, fig. 2

Description : Leaf elliptically ovate, 5 to 9 cm long and 2.3 to 3 cm wide, acuminate at apex, obtuse at base; margin crenate with sporadic minute spine; primary vein moderate, slightly curved; secondary veins 7 subopposite pairs, diverging at angles of 30 to 40 degrees gently curving up and making loops with superadjacent secondaries; tertiary and higher order veins obscure; petiole missing.

Remarks : This species is based on one complete leaf and a fragment. They have the typical margin of the modern *Deutzia scabra* THUNBERG and is referred to this species.

The living species in widely growing in the cool- to warm-temperate zones of Hokkaido, Honshu, Shikoku, Kyushu, Amami-oshima and China.

Collection : SFPG no. 126.

Genus *Hydrangea* LINNAEUS

Hydrangea hirta (THUNBERG) SIEBOLD
Pl. 13, fig. 4

1940. *Hydrangea hirta* (THUNBERG) SIEBOLD; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 63, pl. 11, fig. 1.

Remarks : No fossil materials of this species were found in the collection of author. But ENDO (1940) figured a leaf specimen of the present species and the writer reinvestigated it in detail.

His specimen, though lacking one third of the blade and obscure fine vanation, may fall within the range of existing species by size, obovate foliar shape and coarsely simple serrate margin.

The living *Hydrangea hirta* (THUNBERG) SIEBOLD is mainly distributed from the warm-temperate zone of the Kanto district and extends westward to Kyushu, Japan.

Collection : IGPS Reg. no. 60930.

Hydrangea paniculata SIEBOLD
Pl. 14, figs. 1, 2

1940. *Hydrangea paniculata* SIEBOLD; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 63, pl. 8, figs. 9, 20, 25.

Remarks : The present species is represented by many leaves and some calyces, and is characterized by the following features: Leaves elliptical in general outline, obtuse or rounded base, caudate-acute apex, fine serration with falcate-acuminate teeth and venation camptodromous; sepals 4 in numbers, orbicular in shape, 1cm long and reticulately veins.

The examined specimens are assignable to the modern *Hydrangea paniculata* SIEBOLD, which is widely distributed in the cool-temperate zone of Japan.

Collection : SFPG nos. 27, GSJ F8033.

Hydrangea petiolaris SIEBOLD et ZUCCARINI
Pl. 14, fig. 5

Description : Leaf orbicular, obtuse with cuspidate at apex, truncate or rather cordate at base; 4.8 to 5.7 cm long and 4 to 5 cm wide; primary vein medium; secondary veins 5 alternate pairs, variable as to spacing and angle of divergence, curving up and making loops near the margin; tertiaries in intercostal area weakly percurrent; quaternary veins orthogonal reticulate; margin serrulate, marginal teeth triangular, straight on the apical side and concave on the basal side; petiole more than 6 mm long.

Remarks : One almost complete leaf specimen and a fragment were examined. They have several characteristics as described above that indicate the living *Hydrangea petiolaris* SIEBOLD et ZUCCARINI.

This modern liana is widely growing in the cool-temperate zone of Japan and extends to southern Korea and Sakhalin.

Collection : SFPG no. 124.

Genus *Philadelphus* LINNAEUS

Philadelphus satsumanus SIEBOLD
Pl. 13, fig. 7

Description : Leaf ovate, 3.6 cm long and 1.7 cm wide, apex acute and base obtuse; margin sporadic minute teeth with gland-like tips; venation suprabasal imperfect acrodromous; primary vein weak, nearly straight; one pair of secondaries leaving from the primary vein at angles of 40 degrees near the base, curving up along the margin with sinuous course, lateral primaries weak, leaving from the midvein at angles of 25 degrees, curving upward about two-third of the leaf length from the base and making a series of loops with joining tertiary veins, weak secondaries diverging from the middle to upper part of the midvein with random angles and with irregular space, secondaries diverging from the lateral primaries making loops near the margin; tertiary veins and ultimate veinlets obscure; petiole stout, 4 mm long.

Remarks : A single complete leaf specimen, though very small for the present species, is identical to *Philadelphus satsumanus* SIEBOLD by the characters described above. This modern species is distributed mainly in the warm-temperate zone of Honshu, Shikoku and Kyushu, Japan.

Collection : SFPG no. 149.

Genus *Ribes* LINNAEUS

Ribes ambiguum MAXIMOWICZ
Pl. 12, fig. 6; text-fig. 8

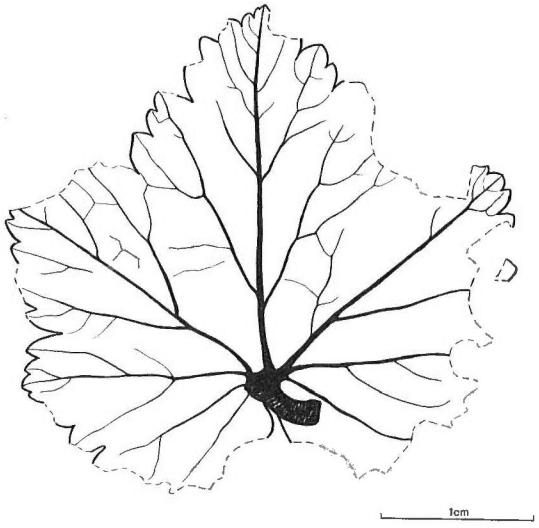
Description : Leaf pentagonally reniform in general outline, apex acute and base deeply cordate; 3.1 cm long and 3.2 cm wide; venation thin, five primary veins radiate from the base, each primaries straight, ending in lobe apex; secondary veins weak, diverging low angles from the primaries, forking once or twice and ending directly into the marginal teeth; tertiary veins obscure; margin crenate with minute teeth; petiole stout, more than 5 mm long.

Remarks : Only one but almost complete leaf impression is identical to the modern *Ribes ambiguum* MAXIMOWICZ in its pentagonal outline, fine serrate margin with obtuse tips and radially extending venation (text-fig. 8). This modern shrub grows on the big trees such as *Fagus crenata* and *Quercus mongolica* var. *grosseserrata*. It is distributed in the cool-temperate zone of Honshu, Shikoku and Kyushu in Japan as well as in China.

Collection : SFPG no. 70.

Ribes fasciculatum SIEBOLD et ZUCCARINI
Pl. 12, fig. 3

Description : Leaves small in size, palmately 3 or 5 lobed, pentagonal in general outline, cordate at base, 1.8 to 3.8 cm long and 2.4 to 4 cm wide (estimated); each lobe ovate in shape, acute at apex; margin incised serrate with obtuse teeth; primary vein 3 or 5 in number, nearly straight; secondary veins slender, 3 to 5 pairs ending marginal teeth, craspedodromous; petiole 8 to 10 mm long.



Text-fig. 8 Venation characters of fossil *Ribes ambiguum* MAXIMOWICZ. SFPG no. 70, ×2.

Remarks : A few leaf specimens are referred to *Ribes fasciculatum* SIEBOLD et ZUCCARINI by their pentagonal foliar shape and incised serration with obtuse teeth. The extant species is growing in the cool- to warm-temperate zones of Honshu, Shikoku and Kyushu in Japan and extends to Korea and China.

Collection : SFPG no. 138.

Genus *Rodgersia* A. GRAY

Rodgersia podophylla A. GRAY

Pl. 14, fig. 8

Description : Leaflet trilobed, obovate in general outline; base cuneate, 15 cm long (estimated) and 8 cm wide (estimated) ; a pair of acute lateral lobes and an apical lobe separated by acute sinuses; margin serrate with densely arranged teeth, marginal teeth triangular, straight on the apical side and straight to concave on the basal side with acute tips; midvein moderate, running slightly curved, secondary veins subopposite, 9 pairs, basal 4 pairs making angles of 40 to 45 degrees with the midvein, brochidodromous, fifth secondaries from the base rather stout, leaving straight and enter the lateral lobes, tertiary veins in the marginal area extending from the marginal loops of the secondaries and entering the marginal teeth.

Remarks : A single incomplete leaflet is examined. It is identical to those of the living *Rodgersia podophylla* A. GRAY by the characteristic obovate shape and cuneate base.

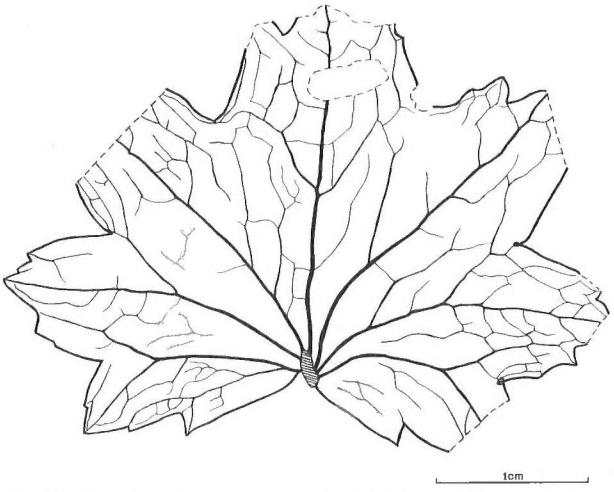
This living perennial herb grows in the cool-temperate zone of Japan and Korea.

Collection : SFPG no. 162.

Genus *Saxifraga* LINNAEUS

Saxifraga fortunei HOOKER
Pl. 14, fig. 3; text-fig. 9

Description: Leaves reniform in general outline, palmately 7-lobed with broadly short lobes and shallowly acute sinuses, cordate at base, each apex acute, 3 to 5.4 cm long and 4.2 to 6.2 cm wide; margin dentate at apex of each spreding lobe; venation actinodromous, weak, reticulate; petiole more than 4 cm long.



Text-fig. 9 Venation characters of fossil *Saxifraga fortunei* HOOKER. GSJ F8063, ×2.

Remarks: The present species is not so common in the Shiobara fossil flora. It is characterized by palmately 7-lobed foliar shape and weak primaries and is similar to the existing *Saxifraga fortunei* HOOKER.

The living species is widely distributed in the subarctic to cool-temperate zones of Japan and extends to Korea, Sakhalin and China.

Collection: SFPG no. 127, GSJ F8063.

Genus *Schizophragma* SIEBOLD et ZUCCARINI

Schizophragma hydrangeoides SIEBOLD et ZUCCARINI
Pl. 12, fig. 7

1940. *Schizophragma hydrangeoides* SIEBOLD et ZUCCARINI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 4, p. 64, pl. 11, fig. 24.

Remarks: The present species is represented by two leaves in the collection. They are characterized by broadly ovate shape, acuminate apex, rounded to truncate base, triangular marginal teeth with incurved acute tips. This modern deciduous liana widely flourishes in the cool-temperate zone of Japan.

Collection: SFPG no. 71.

Family Rosaceae

Genus *Aruncus* KOSTELETZKY

Aruncus sylvester KOSTELETZKY
Pl. 14, fig. 7

Description : Leaflet obliquely ovate, acuminate apex and oblique base, 4.7 cm long and 3.1 cm wide; margin incised with doubly serrulate teeth, sinuses shallow and attenuate; venation pinnate, primary vein stout, nearly straight, taper to a point; secondary veins craspedodromous, subopposite to alternate 8 to 10 pairs, basal pairs making angles of 70 to 80 degrees with midvein, the upper pairs gradually decreasing the angle to the apex and the uppermost pair making angles of about 20 degrees, gently curving up and enter the teeth, tertiary veins in the intercostal area percurrent, while the tertiaries in the marginal area extending from the secondaries entering the marginal teeth; petiolule absent.

Remarks : A single complete leaflet is identical to *Aruncus sylvester* KOSTELETZKY in their foliar shape, marginal serration and venation. This modern species of perennial herb widely distributed in the cool-temperate zone of the northern hemisphere.

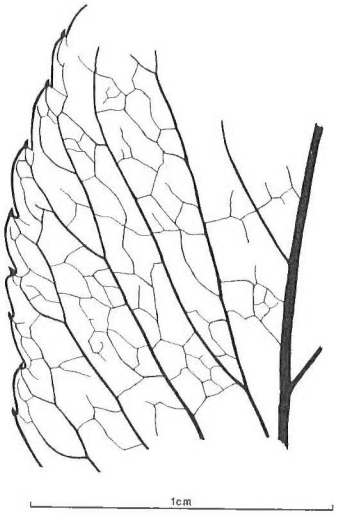
Collection : SFPG no. 129.

Genus *Chaenomeles* LINDLEY

Chaenomeles japonica (THUNBERG) LINDLEY
Pl. 14, fig. 4; text-fig. 10

Description : Leaf obovate, 4.2 cm long and 1.9 cm wide, apex rounded and base cuneate with the blade decurrent along the petiole; margin crenate smoothly rounded, convex on the basal side of the teeth with sharp tips; primary vein moderate, weakly sinuous; secondary veins weak, camptodromous, extending from the midvein at angles of 20 to 30 degrees, tertiary veins obscure; petiole stout, 7 mm long.

Remarks : A complete leaf impression is referred to *Chaenomeles japonica* (THUNBERG)



Text-fig. 10 Venation characters of fossil *Chaenomeles japonica* (THUNBERG) LINDLEY. SFPG no. 132, ×4.

LINDLEY by characteristic obovate foliar shape, cuneate at base, serrate to crenate margin with sharp tips and weak secondary venation (text-fig. 10).

The extant deciduous small tree is distributed in the cool- to warm-temperate zones of Japan except for Hokkaido.

Collection : SFPG no. 132.

Genus *Crataegus* LINNAEUS

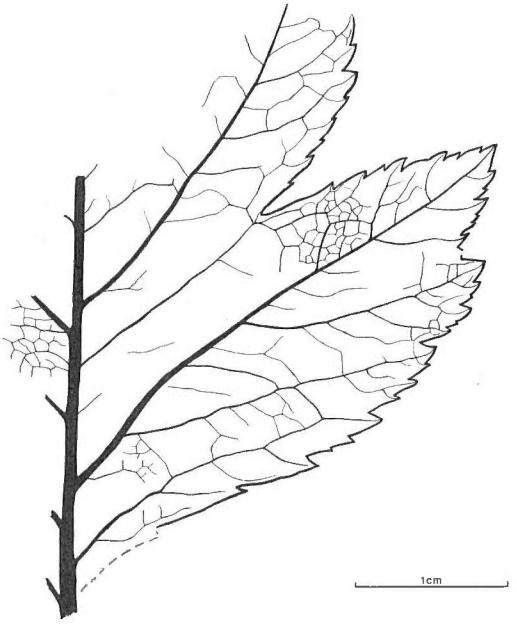
Crataegus maximowiczii C. K. SCHNEIDER

Pl. 15. fig. 5; text-fig. 11

Description : Leaves bloadly oval to rhombic in general outline, acute at apex, widely cuneate and slightly decurrent at base, pinnately divided about half way to midrib with accuminate sinuses at the bottom; margin double serrate with acute teeth, 4 to 6.2 cm long, 3.7 to 5.7 cm wide; primary vein moderate, straight or rather flexuous; secondary veins 4 to 6 alternate pairs, diverging from the midrib at angles of about 40 to 50 degrees, the lowest pair curving down and the upper pairs curving up, ending in the principal teeth of each lobe; intersecondary veins extending to the sinuses and forking near the bottom of sinuses; tertiary veins random reticulate in intercostal area and ending marginal teeth in marginal area; quaternary and higher order veins orthogonal reticulate; ultimate veinlets more than once branched.

Remarks : The present specimens consist of four leaves including almost complete one. They are all identical to *Crataegus maximowiczii* C. K. SCHNEIDER in their pinnati-lobate leaf character. This deciduous small-tree is now distributed mainly in the cool-temperate zone of Hokkaido, Sakhalin, Korea and Northern China.

Collection : SFPG no. 133.



Text-fig. 11 Venation characters of fossil *Crataegus maximowiczii* C. K. SCHNEIDER. SFPG no. 133, ×2.

Genus *Kerria* DE CANDOLLE

Kerria japonica (THUNBERG) DE CANDOLLE
Pl. 15, fig. 2

Description : Leaflets ovate to oval in general outline, acuminate at apex, acute to obtuse at base, 5.5 to 10.5 cm long and 3.2 to 6.2 cm wide; margin cleft and double serrate; primary vein medium, straight or slightly curved; secondary veins 12 to 14 alternate to subopposite pairs, diverging at various angles from 50 to 65 degrees, ending directly in the largest teeth; tertiary veins percurrent; quaternary veins orthogonal reticulate; petiolules less than 2 mm long.

Remarks : The above-described characters suggest that these leaflet specimens are related to the living *Kerria japonica* (THUNBERG) DE CANDOLLE growing in the cool- to warm-temperate zones of Japan and China.

The present species is a new record of the fossil from the Shiobara fossil flora.

Collection : SFPG no. 75.

Genus *Malus* MILLER

Malus sieboldii (REGEL) REHDER
Pl. 14, fig. 6

Description : Leaf elliptical, apex acute, base obtuse, 6.9 cm long and 4 cm wide; primary vein stout, nearly straight; secondary veins 8 alternate pairs, irregularly spaced, emerging from the primaries at variable angles from 40 to 55 degrees, giving off some branches or forking near the margin, ending in the larger teeth or making loops; tertiary veins irregularly percurrent; quaternary veins making mainly pentagonal meshes between the tertiaries; ultimate veinlets not well preserved, branched more than once; margin doubly serrate with acute teeth, marginal teeth various sized with glandular apex, straight to sometimes sigmoidal on apical side and convex on basal side; petiole stout, sulcated above and dilated at base, 2.7 cm long.

Remarks : A single complete and two incomplete leaves are identical with *Malus sieboldii* (REGEL) REHDER in the characters mentioned above. This deciduous small tree is growing in the cool-temperate zone of Japan and Korea.

Collection : SFPG no. 76.

Genus *Potentilla* LINNAEUS

Potentilla fragarioides var. *major* MAXIMOWICZ
Pl. 15, figs. 3, 4

Description : Leaves pinnate, with 5 or more leaflets, terminal leaflet rhombic obovate, lateral leaflets asymmetrical ovate; terminal leaflets largest, 3.2 to 4.5 cm long and 1.7 to 3 cm wide, apex acute, base acute or obtuse; margin lobed, acute teeth, sinus acuminate; primary vein medium, straight or rather curved; secondary veins 4 to 7 alternate to subopposite pairs, diverging at angles of 30 to 40 degrees, ending directly tips of each lobe; tertiary veins diverging from the secondaries reaching the sinus bottoms or making loops

near the margin; quaternary and higher order veins obscure; basal leaflets smallest, 7 to 9 mm long and 4 mm wide; petiolules less than 2 mm long or absent.

Remarks : The present species is based on two incomplete leaves with some complete leaflets. These specimens are identical to the living *Potentilla fragarioides* var. *major* MAXIMOWICZ which widely flourishes in the cool- to warm-temperate zones of the north-eastern Asia.

Collection : SFPG nos. 74, 142.

Genus *Pourthiaea* DECAISNE

Pourthiaea villosa (THUNBERG) DECAISNE

Pl. 15, fig. 6

Description : Leaves variable in shape, oblanceolate to wide obovate in general outline, accuminate at apex, accuminate to acute at base, 3.8 to 6.2 cm long and 1.4 to 2.8 cm wide; margin serrulate with a minute teeth on some of the major teeth; marginal teeth small, densely arranged, nearly straight on the apical side and convex on the basal side; venation brochidodromous; primary vein moderate, straight; secondary veins thin, 6 to 9 alternate to subopposite pairs, variable as to spacing and angle of divergence from the primaries; tertiary veins forming a coarse polygonal network; quaternary veins orthogonal reticulate, ultimate branching more than once; petiole short, 3 to 5 mm long.

Remarks : These leaves are variable in shape, but marginal characters correspond to those of the living *Pourthiaea villosa* (THUNBERG) DECAISNE. The modern species of deciduous small tree is widely distributed in the cool- to warm-temperate zones of Honshu, Shikoku and Kyushu in Japan and extends to Korea, China and Thailand.

Collection : SFPG no. 93.

Genus *Prunus* LINNAEUS

Prunus apetala (SIEBOLD et ZUCCARINI) FRANCHET et SAVATIER

Pl. 15, fig. 1

1940. *Prunus maximowiczii* RUPRECHT; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 66, pl. 5, figs. 12, 18; pl. 10, fig. 12.

Description : Leaves obovate in general outline, acuminate or caudately acuminate at apex, rounded to obtuse at base, 4.5 to 9.5 cm long (estimated) and 2.7 to 5.1 cm wide; margin inciso-duplicately serrulate with short obtuse to acute teeth, ending in glands; primary vein weak, straight; secondary veins 8 to 9 alternate pairs, irregularly spaced, diverging at angles of 35 to 45 degrees, nearly straight or slightly curving upward and making loops near the margin; tertiary veins irregularly percurrent; quaternary and higher order venation obscure; petiole more than 5 mm long, a pair of glands situated at the base of lamina.

Remarks : Some complete leaf impressions are suggestive of *Prunus* and especially of *P. apetala* (SIEBOLD et ZUCCARINI) FRANCHET et SAVATIER in their characteristic marginal teeth, obovate shape of lamina with caudate apex.

This modern species is fairly common in the cool-temperate zone of Honshu, Shikoku

and Kyushu, Japan.

Three fragmental leaves described by ENDO (1940) under the name of *Prunus maximowiczii* RUPRECHT may be referred to the present species by their marginal character which has inciso-duplicately serrulate with short obtuse teeth. While *Prunus maximowiczii* has double serrulate with short falcately teeth and sharp points.

Collection : SFPG no. 25.

Prunus jamasakura SIEBOLD ex KOIDZUMI
Pl. 15, fig. 11

Description : Leaves obovate, apparently abruptly cuneate at apex, rounded at base, 5.2 to 7.8 cm long and 2.9 to 4.9 cm wide; margin simply or subduplicately serrulate, acuminate teeth with minute glands on the tip; venation pinnate, brochidodoromous; primary vein moderate, straight; secondary veins 10 to 13 pairs, alternate to subopposite, irregularly spaced, diverging at angles of 35 to 45 degrees, nearly straight or slightly curving upward, making loops near the margin; tertiary veins percurrent; quaternary veins orthogonal reticulate; ultimate obscure; petiole stout, more than 1.2 cm long, a pair of glands near the base of blade.

Remarks : Some well preserved leaf impressions are same as the extant *Prunus jamasakura* SIEBOLD ex KOIDZUMI which is the most common wild cherry tree in the cool- to warm-temperate zones of central and southern Japan.

Collection : SFPG no. 77.

Prunus maximowiczii RUPRECHT
Pl. 15, fig. 10

Description : Leaves obovate in general outline, acuminate at apex and rounded or truncate at base, 5.2 cm long and 2.8 cm wide; margin serrate, regular spacing; shortly falcate teeth, concave or acuminate on apical side and convex on basal side, glands on tips; primary vein thin, nearly straight; secondary veins 7 alternate pairs, brochidodromous, diverging at angles of 40 to 50 degrees; tertiary veins irregularly percurrent.

Remarks : Three leaves in the collection are identical to the existing *Prunus maximowiczii* RUPRECHT in their foliar shape, size and marginal feature.

The modern species is distributed in the cool-temperate zone of Japan, Sakhalin, Korea and China.

Collection : SFPG no. 186.

Prunus nipponica MATSUMURA
Pl. 15, fig. 7

Description : Leaves obovate in general outline, 4.2 to 4.4 cm long, 2.5 to 2.7 cm wide, abruptly cuneate at apex, acute or rounded at base; margin duplicately serrate with minute glands on the tip; venation pinnate, semicraspedodromous; primary vein moderate, straight; secondary veins 9 alternate to subopposite pairs, diverging from the primaries at variable angles from 35 to 60 degrees, nearly straight or slightly curving up, entering directly

large teeth or making loops with superadjacent secondaries; tertiary veins at intercostal area percurrent, tertiaries at marginal area entering large teeth or forming small loops; quaternary and higher order veins forming random networks; petiole 1 cm long.

Remarks : Two complete leaf specimens are referred to *Prunus* and are especially identical to *Prunus nipponica* MATSUMURA by their shape, margin and venation characters.

This small deciduous tree is commonly found in the alpine and subalpine zones of central and northern Japan.

Collection : SFPG no. 115.

Prunus sargentii REHDER
Pl. 16, fig. 1

Description : Leaves orbicular or oboval in general outline, apex obtuse with cuspidate, base rounded or slightly cordate, 8.6 to 10.3 cm long and 6 to 7.3 cm wide; margin single serrulate with glandular teeth and rarely accompanied subsidiary minute teeth; venation pinnate, brochidodromous; primary vein moderate, nearly straight or slightly curved near the base; secondary veins 11 to 13 pairs, alternate, irregularly spaced, diverging at angles of about 50 degrees in the middle part and about 85 degrees in the basal part, gently curving up and making loops near the margin; tertiary veins irregularly percurrent; quaternary and higher order veins indistinct; petiole 1.8 cm long, having a pair of glands.

Remarks : These leaves are similar to *Prunus sargentii* REHDER and *P. jamasakura* SIEBOLD ex KOIDZUMI in general appearance. The examined specimens more resemble those of the former one in their cordate base and broader shape.

This modern species is a representative cherry tree in the cool-temperate zone of northern Japan, Sakhalin and Korea.

Collection : SFPG no. 78.

Prunus ssiori FR. SCHMIDT
Pl. 15, fig. 9

Description : Leaf oblongly ovate, accuminate at apex, slightly cordate at base, 7.4 cm long and 3.6 cm wide; margin serrulate with attenuate teeth; marginal teeth densely arranged, concave to sigmoidal on apical side and sigmoidal to convex on basal side with hairly point; venation pinnate, brochidodromous; primary vein moderate, nearly straight; secondary veins rather thin, 12 alternate pairs, diverging at angles of about 50 degrees in the basal part, at 60 to 70 degrees in the middle and the apical parts, extending slightly curving up, making loops with the superadjacent secondary veins; intersecondary veins often developing but slender; tertiary veins irregularly percurrent; quaternary and higher order veins not well preserved; petiole 6 mm long with two glands on the upper portion.

Remarks : A single almost complete leaf impression is identical to *Prunus ssiori* FR. SCHMIDT by oblongly ovate foliar shape, slightly cordate base and marginal character.

This extant species is widely distributed in the cool-temperate zone of northeastern Asia, especially very common in Hokkaido.

Collection : SFPG no. 79.

Genus *Pyrus* LINNAEUS

Pyrus pyrifolia (BURMAN) NAKAI
Pl. 16, fig. 8

Description : Leaves oval to orbicular, obtuse with cuspidate or accuminate at apex, rounded or slightly cordate at base, 3, to 6 cm long (estimated) and 2.6 to 3.8 cm wide; margin serrulate with attenuate teeth; marginal teeth small, densely arranged, concave to sigmoidal on the apical side, convex on the basal side; primary vein moderate, straight; secondary veins thin, 5 to 8 alternate to subopposite pairs, diverging at angles of 60 degrees in the basal part, at 45 to 50 degrees in the middle part and at 30 degrees in the apical part, gently curving up, joining with the branches of superadjacent secondary veins and making parallelogram-like network in marginal area; intersecondary veins often developing but slender; tertiary veins approximately at right angles with the midvein; quaternary veins making irregularly reticulate; ultimate veinlets obscured; petiole medium, more than 3.5 cm long.

Remarks : These fossil leaves are identical to *Pyrus pyrifolia* (BURMAN) NAKAI in their marginal feature, tertiary venation and long petiole.

This living deciduous tree grows in the cool- to warm-temperate zones of Honshu, Shikoku and Kyushu in Japan and extends to southern Korea and China.

Collection : SFPG no. 80.

Genus *Rosa* THUNBERG

Rosa multiflora THUNBERG
Pl. 16, figs. 5, 6

1937. *Rosa polyantha* SIEBOLD et ZUCCARINI; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 316, fig. 5F.
1954. *Rosa multiflora* THUNBERG; TAKAHASHI, *Mem. Fac. Sci. Kyushu Univ.*, ser. D. vol. 5, no. 1, p. 58, pl. 6, figs. 5a-m.
1971. *Rosa multiflora* THUNBERG; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 31, pl. 6, fig. 11.

Remarks : Several complete leaflets have small, elliptical foliar shape and mainly single serrulate margin. These leaflets are similar to the extant *Rosa multiflora* THUNBERG growing in Japan and Korea.

Besides, many twig and prickles are found from the upper Pliocene *Stegodon* beds by MIKI (1937) under the name of *Rosa polyantha* (Syn. *Rosa multiflora*). A lot of leaflets and some prickles of the present species were reported by TAKAHASHI (1954) from the upper Pliocene Oya formation in Kyushu.

Collection : SFPG nos. 81, 197.

Genus *Rubus* LINNAEUS

Rubus crataegifolius BUNGE
Pl. 16, fig. 3

Description : Leaf large in size, palmately 5-lobed, pentagonal in general outline, middle lobe largest, oblong, lateral lobes ovate, basal pair of lobes smallest, 9.5 cm long and 7.5 cm wide (estimated), base cordate; margin serrulate; venation actinodromous, the medial

primary vein stout with some prickles, the lateral pair making angles of 55 to 60 degrees with the medial, and the basal pair about 120 degrees with the medial; secondary veins of the medial lobe about 8 pairs, subopposite, diverging at angles of 50 to 65 degrees, straight to the margin and enter the marginal teeth, tertiary veins in costal area percurrent, petiole stout with four prickles, dilated at base, 3.2 cm long.

Remarks : A single almost complete leaf is referred to the genus *Rubus* by the foliar shape and many prickles on the petiole and venations. This specimen is identical to the extant *Rubus crataegifolius* BUNGE growing in mainly warm-temperate zone of Honshu, Shikoku, Kyushu, Japan and extends to Korea and China.

Collection : SFPG no. 130.

Rubus palmatus THUNBERG
Pl. 16, fig. 4

Description : Leaves small in size, narrowly ovate in general outline, 3.5 to 5 cm long and 1.8 to 2.5 cm wide, acuminate apex and slightly cordate base; margin doubly serrulate; venation actinodromous, five primaries diverging at base, the medial primary vein stout, nearly straight, lateral primaries weak, making angles of 60 degrees with the medial, curving up and entering marginal teeth, the basal primaries making angles of 90 degrees with the medial, slightly curved and end at marginal teeth; secondary veins from medial about 5 pairs, subopposite, craspedodromous, petiole stout with a pair of prickles, 1.4 cm long, dilated at base.

Remarks : This newly found species from the Shiobara fossil flora is represented by three almost complete leaves. They are characterized by actinodromous venation, prickles on the petiole. The living deciduous small tree is mainly distributed in the warm-temperate zone of the western Honshu, Shikoku, Kyushu, Japan and also in China and Korea.

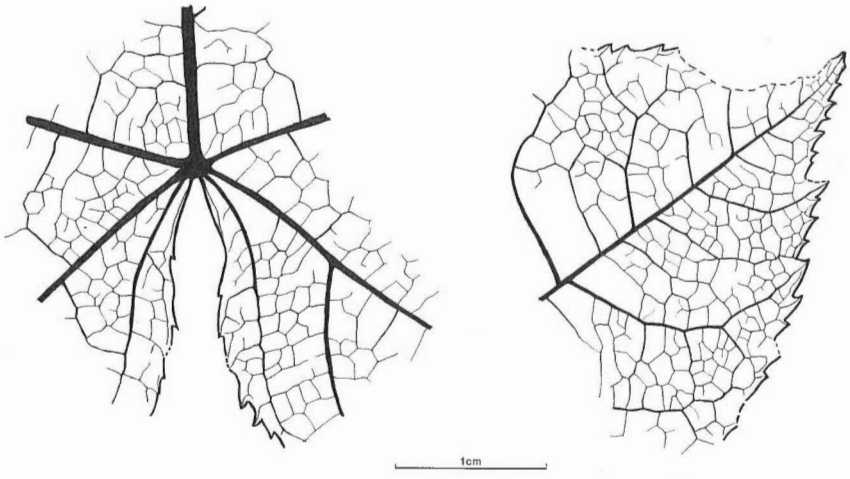
Collection : SFPG no. 82.

Rubus sp.
Pl. 16, fig. 7; text-fig. 12

Description : Leaf pentagonal in general outline, palmately 5-lobed, deeply cordate at base, 9 cm long (estimated) and 8.8 cm wide; lateral lobes acute at apex, doubly serrulate on margin; central lobe largest, lateral lobes medium in size; basal lobes smallest; each sinus obtuse; primary veins five in number, nearly straight and caudate on apical part; secondary veins slender 4 or 5 pairs, mostly arising up near the margin, camptodromous; tertiary veins slender, irregularly percurrent or forming polygonal network; petiole more than 4 cm long.

Remarks : A single incomplete specimen is identified with the Genus *Rubus* by its general appearance. The examined leaf is rather similar to the extant *R. buerteri* MIQUEL by its pentagonal foliar shape, deeply cordate base, fine serrate with acute teeth and long petiole. *R. buerteri* is now growing in the warm-temperate zone of Japan, south Korea, Formosa and China.

Collection : SFPG no. 137.



Text-fig. 12 Venation characters of fossil *Rubus* sp.. SFPG no. 137, ×2.

Genus *Sorbus* LINNAEUS

Sorbus alnifolia (SIEBOLD et ZUCCARINI) C. KOCH
Pl. 16, fig. 9

1888. *Alnus* or *Betula* sp.; NATHORST, *Pal. Abh.* vol. 4, no. 3, p. 31, pl. 10, fig. 9.

1940. *Micromeles alnifolia* KOEHNE; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 65, pl. 4, fig. 5.

1940. *Micromeles alnifolia* KOEHNE; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 18, figs. 9, 16.

Remarks : A number of leaves are referred to *Sorbus alnifolia* (SIEBOLD et ZUCCARINI) C. KOCH in foliar shape and doubly serrate margin. The living species is widely distributed in the cool-temperate zone through Japan, Korea and China.

Micromeles alnifolia, described by ENDO (1940) and KOIDZUMI (1940) from the Shiobara fossil flora, is the synonym of the present species.

Collection : GSJ F8035.

Sorbus commixta HENDLUND
Pl. 17, fig. 10

1940. *Sorbus commixta* HENDLUND; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 65, pl. 9, fig. 6; pl. 10, fig. 17; pl. 12, fig. 6.

1940. *Sorbus commixta* HENDLUND; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 18, figs. 2, 5, 25.

1940. *Sorbus rufo-ferruginea* C. K. SCHNEIDER; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 66, pl. 12, fig. 5.

Remarks : Many odd-pinnate leaves and detached leaflets are identical with the existing species by their oblong foliar shape, fine duplicate serration on margin, acuminate apex and rounded base. The living *Sorbus commixta* is abundantly found in the cool-temperate and subalpine forests of Japan, Sakhalin and Korea.

One of the figured specimen by ENDO (1940) under the name of *Sorbus rufo-ferruginea* C. K. SCHNEIDER from the Shiobara fossil flora (pl. 12, fig. 5) is similar to the present species.

Collection : GSJ F 8036.

Sorbus gracilis (SIEBOLD et ZUCCARINI) C. KOCH
Pl. 16, fig. 2

Description : Leaflet obovate, 3.9 cm long and 1.7 cm wide, rounded at apex, cuneate at base; margin bluntly serrate in the upper half of the blade and entire in the lower half; venation pinnate, mixedcraspedodromous.

Remarks : Two leaflet specimens were examined. At a glance, these specimens resemble to those of the living *Sorbus gracilis* (SIEBOLD et ZUCCARINI) C. KOCH and *Sorbus commixta* HENDLUND in their general appearance. The former has single marginal serration with bluntly dentation, while the latter has fine duplicate serration on the margin of the blade, acuminate apex and rounded base. The examined specimens are referred to *Sorbus gracilis* (SIEBOLD et ZUCCARINI) C. KOCH, which is growing in the cool-temperate zone of the Kanto district, extending westward into Shikoku and Kyushu, Japan.

Collection : SFPG no. 83.

Sorbus japonica (DECAISNE) HEDLUND
Pl. 17, fig. 1

1940. *Micromeles japonica* KOEHNE; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 65, pl. 4, fig. 13.

Remarks : Several complete specimens do not differ from the existing *Sorbus japonica* (DECAISNE) HEDLUND (Syn. *Micromeles japonica* KOEHNE) in the incised duplicate dentations and the straight and slender secondary veins which are its characteristic features. This deciduous tree is distributed in the cool-temperate zone of Honshu, Shikoku and Kyushu, Japan.

Collection : GSJ F7536.

Genus *Stephanandra* SIEBOLD et ZUCCARINI

Stephanandra incisa (THUNBERG) ZABEL
Pl. 15, fig. 8

Description : Leaf small in size, deltoid, 2.5 cm long and 2.2 cm wide, apex acuminate and base cordate; margin pinnately lobed, each lobe separated by acuminate sinuses, doubly serrate; venation pinnate, primary vein weak, slightly curved, secondary veins opposite, 6 pairs, the basal pair making angles of 90 degrees with the midvein, the upper pairs gradually decreasing the angle to the apex, spreading from the midvein and enter the tips of each lobe; petiole 5 mm long.

Remarks : The present species is represented by a single complete leaf and some fragments. The examined specimens have deltoid foliar shape, incised doubly serrate margin and is identical to the modern species of *Stephanandra incisa* (THUNBERG) ZABEL.

This is a deciduous small tree growing in the cool- to warm-temperate zones of Japan, Korea and China.

Collection : SFPG no. 84.

Family Leguminosae

Genus *Cladrastis* RAFINESQUE

Cladrastis platycarpa (MAXIMOWICZ) MAKINO
Pl. 17, fig. 8

Description : Legumes flat, elliptical, 4.8 cm long and 1.4 cm wide, base acuminate, apex acuminate with pin-like tip, winged all round.

Remarks : A single complete and several incomplete legumes are obtained. These specimens are identical to *Cladrastis platycarpa* (MAXIMOWICZ) MAKINO in having wing all round.

The modern species is growing in the cool- to warm-temperate zones of Honshu and Shikoku, Japan.

Collection : GSJ F12713.

Genus *Dumasia* DE CANDOLLE

Dumasia truncata SIEBOLD et ZUCCARINI
Pl. 17, fig. 3

Description : Leaflet asymmetrically ovate, 6.1 cm long and 2.6 cm wide; margin entire, apex obtuse with cuspidate tip, base oblique; primary vein moderate rather sinuous; secondary veins varies irregularly space and angles, camptodromous; tertiary veins in the intercostal area coasely percurrent; petiolule absent.

Remarks : Only one complete leaflet is examined. It is identical to the living *Dumasia truncata* SIEBOLD et ZUCCARINI by asymmetrical ovate foliar shape and varies secondary vein characters.

This penennial herb is growing in the warm-temperate zone of Honshu, Shikoku and Kyushu, Japan.

Collection : SFPG no. 160.

Genus *Gleditsia* LINNAEUS

Gleditsia japonica MIQUEL
Pl. 17, fig. 4

1937, *Gleditsia japonica* MIQUEL; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 318, figs. 6A-E.
1938. *Gleditsia japonica* MIQUEL; MIKI, *Jap. Jour. Bot.*, vol. 9, p. 15, fig. 2K; p. 218, fig. 5F.
1940. *Macckia amurensis* var. *buergeri* C. K. SCHNEIDER; ENDO, *Sci. Rep, Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 67, pl. 11, fig. 17.
1971. *Gleditsia japonica* MIQUEL; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 32, pl. 6, figs. 16. 17.

Remarks : Several small leaflets are characterized by asymmetrically ovate foliar shape, undulate margin. They are identical to the living *Gleditsia japonica* MIQUEL which is distributed in the cool- to warm-temperate zones of western Honshu, Shikoku and

Kyushu, Japan.

The attached leaflets described by ENDO (1940) as *Macckia amurensis* var. *buergeri* C. K. SCHNEIDER are referred to *Gleditsia japonica* by their foliar shape, undulate margin and emarginate apex.

Collection : SFPG no. 86.

Genus *Macckia* RUPRECHT et MAXIMOWICZ

Macckia amurensis var. *buergeri* (MAXIMOWICZ)

C. K. SCHNEIDER

Pl. 17, fig. 2

1971. *Macckia amurensis* var. *buergeri* (MAXIMOWICZ) C. K. SCHNEIDER; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 33, pl. 6, fig. 18; pl. 7, fig. 1.

Remarks : Two perfect and some fragmentary leaflets were examined. They are characterized by elliptical in foliar shape, entire margin and petiole with fine stripes. These specimens are identical to *Macckia amurensis* var. *buergeri* (MAXIMOWICZ) C. K. SCHNEIDER which is widely found in the cool-temperate zone of Hokkaide, Honshu of Japan, Korea and China.

Some leaflets were described as *Macckia amurensis* var. *buergeri* from the Shiobara fossil flora (ENDO, 1940) are distinguished from the examined species by their emarginate apex, undulate margin and densely arranged secondary veins.

Collection : SFPG no. 141.

Genus *Wisteria* DE CANDOLLE

Wisteria floribunda (WILLDENOW) DE CANDOLLE

Pl. 17, fig. 5

1937. *Wisteria floribunda* (WILLDENOW) DE CANDOLLE; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 318, fig. 6F-H.

1938. *Wisteria floribunda* (WILLDENOW) DE CANDOLLE; MIKI, *Jap. Jour. Bot.*, vol. 9, p. 218, fig. 5G; p. 223, fig. 6J; p. 234, fig. 14K.

1971. *Wisteria floribunda* (WILLDENOW) DE CANDOLLE; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 33, pl. 7, fig. 2.

Remarks : The present species is based on some leaflets, and is identical to *Wisteria floribunda* (WILLDENOW) DE CANDOLLE by their oblong foliar shape and venation characters. This deciduous liana is growing in the cool- to warm-temperate zones of Japan.

MIKI (1937) described many leaflets and pods of the present species from the upper Pliocene *Stegodon* beds and he also described winter bud and stalk from the upper Pliocene to Pleistocene sediments (MIKI, 1938). ONOE (1971) described some leaflets of the present species from the interglacial age of the Pleistocene Ebino flora. These leaflets are similar to those of the Shiobara fossil flora.

Collection : SFPG no. 87.

Family Euphorbiaceae

Genus *Sapium* PATRICK BROWNE

Sapium japonicum (SIEBOLD et ZUCCARINI) PAX et HOFFMANN
Pl. 17, fig. 7

Description : Leaves orbicular, 5.5 cm long (estimated) and 4.1 cm wide, apex missing. base rounded; margin entire; venation brochidodromous, primary vein stout, nearly straight, secondary veins 6 opposite pairs, diverging at angles of about 60 degrees, curving upward, making loops near the margin, some glands on loops; tertiary veins missing; petiole stout, a pair of glands situated at the base of lamina.

Remarks : The present species is represented by two rather well preserved specimens. It is referred to the extant species of *Sapium japonicum* (SIEBOLD et ZUCCARINI) PAX et HOFFMANN characterized by glands on the secondary veins near the margin.

The living deciduous small tree is commonly found in the warm-temperate zone to the lower part of the cool-temperate zone, preferring sunny and moderately moist sites on the mountain-side of Honshu, Shikoku, Kyushu and Ryukyu in Japan as well as in China.

Collection : SFPG no. 88.

Family Anacardiaceae

Genus *Rhus* LINNAEUS

Rhus ambigua LAVALLEE ex DIPPEL
Pl. 17, fig. 6

Description : Leaflets variable in shape and size, ovate to oval in general outline, 6 to 9 cm long (estimated) and 3.8 to 5.4 cm wide; venation pinnate, midvein stout, nearly straight, secondary veins rather thin, about 10 alternate pairs, diverging at angles of about 60 degrees, extending straight or slightly curving up, joining with the branches of superadjacent secondary veins.

Remarks : Three leaflets are identical to the extant *Rhus ambigua* LAVALLEE ex DIPPEL in the foliar shape and venation characters. This deciduous liana is distributed in the cool-temperate zones of Asia.

Collection : SFPG no. 90.

Rhus trichocarpa MIQUEL
Pl. 17, fig. 9; pl. 21, fig. 7

Description : Leaflets variable in shape and size, ovate to oblong, 6 to 8.5 cm long, 3 to 4.2 cm wide, apex acute to acuminate, base asymmetrically cuneate; midrib strong, nearly straight, tapered at apical part; secondary veins irregularly spaced, 10 to 13 paris, diverging at angles of 50 to 60 degrees, almost straight and abruptly curving up near the margin, camptodromous; tertiary veins reticulate; margin entire, sometimes a few irregularly coarse incisions on the margin; petiolule almost absent.

Remarks : Some leaflets and a branchlet with fruits were obtained from the Shiobara group. These leaflets are characterized by the above noted features and are identical to the modern *Rhus trichocarpa* MIQUEL.

The fruits is also identical to this species by their shape, size, hispid on the surface and arrangement of fruits. The living deciduous small tree is commonly found on the cool- to warm-temperate mountains in Japan.

Collection : SFPG nos. 91, 92.

Family Aceraceae

Genus *Acer* LINNAEUS

Acer crataegifolium SIEBOLD et ZUCCARINI

Pl. 18, figs. 1, 2

Description : Leaf pentagonal in general outline, 5.5 cm long (estimated) and 5.5 cm wide (estimated), palmately 5-lobed, sinus between each lobes shallow, deeply cordate at base, abruptly acute apex ; margin doubly serrate with bluntly pointed teeth ; lobes short, pointed at apex ; main middle lobe largest, triangular, lateral lobes rather smaller than the middle, obtusely triangular in shape, basal pair of lobes very small about 1 cm long ; medial primary vein moderate, sinuous, lateral primaries diverging from the medial primaries at the angles of 55 degrees, basal pairs at the angles of 110 degrees ; all primaries run into the tips of each lobe ; secondary veins from the midrib diverging at angles of 50 to 60 degrees, 6 pair, subopposite, curving slightly upwards, all secondaries craspedodromous, entering into marginal teeth ; tertiary veins thin, indistinct ; petiole missing.

Samara small, oblanceolate in general outline, 18 mm long and 5 mm wide ; wing rounded at apex, gradually narrowed toward base ; outer margin nearly straight, inner margin gently convex ; seed ellipsoidal in shape, 7 mm long and 3 mm wide ; contact scar 3 mm long ; angles between outer margin of wing and contact scar of seed 80 degrees.

Remarks : The present species is based on a fragmentary leaf and a samara. The leaf is characterized by bluntly pointed teeth of the margin and pentagonal foliar shape and identical to this species. The samara specimen has oblanceolate in general outline, ellipsoidal seed and high angle of attachment. These characters may be included in *Acer crataegifolium* SIEBOLD et ZUCCARINI.

Both the leaf and the samara were newly found from the Shiobara fossil flora.

Collection : SFPG nos. 190, 191.

Acer diabolicum BLUME ex KOCH

Pl. 18, figs. 3, 4

1934. *Acer diabolicum* BLUME ex KOCH ; ENDO, *Jap, Jour. Geol. Geogr.*, vol. 11, nos. 3-4, p. 249, pl. 31, figs. 1, 2 ; pl. 34, fig. 2 ; pl. 35, figs. 4, 5, 15, 18.

1963. *Acer diabolicum* BLUME ex KOCH ; MURAI, *Rep. Techno. Iwate Univ.*, vol. 16, no. 1, p. 100, pl. 12, fig. 7.

1971. *Acer diabolicum* BLUME ex KOCH ; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 34, pl. 7, figs. 5, 6.

Remarks : The present species is represented by some leaves and samaras. Leaves of the present species is characterized by marginal dentation with 2 or 3 obtusely pointed tips.

Samaras are characterized by large size, globose seeds with irregular suture and very acute extension angles of wings. These characters of leaves and samaras well correspond

with those of the extant *Acer diabolicum* BLUME ex KOCH.

The living species is widely distributed in the cool-temperate zone of Honshu, Shikoku and Kyushu together with *Quercus mongolica* var. *grosseserrata*, *Fagus crenata* and many species of the genus *Betula*.

Collection : SFPG no. 11, GSJ F8077.

Acer japonicum THUNBERG
Pl. 18, figs. 7, 8

1934. *Acer japonicum* THUNBERG ; ENDO, *Jap. Jour. Geol. Geogr.*, vol. 11, nos. 3-4, p. 241, pl. 30, figs. 1, 6 ; pl. 32, fig. 5 ; pl. 34, figs. 1, 3 ; pl. 35, figs. 3, 17.

1940. *Acer japonicum* THUNBERG ; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 19, fig. 89.

1963. *Acer japonicum* THUNBERG ; MURAI, *Rep. Techno. Iwate Univ.*, vol. 16, no. 1, p. 104, pl. 17, fig. 2.

Remarks : A lot of leaves are referred to *Acer japonicum* THUNBERG by their 9 to 13-lobed foliar shape, deeply cordate at the base and double serration with acute teeth at the margin.

Fossil fruits of two divergent winged seeds attaching to pedicel are also found. They are similar to those of the present species by their size, thick and globose seeds, 90 degrees of divergent angle.

This maple tree is growing in the cool-temperate zone of Hokkaido and Honshu, Japan.

Collection : SFPG no. 193, GSJ F12714.

Acer micranthum SIEBOLD et ZUCCARINI
Pl. 18, figs. 5, 6

1934. *Acer micranthum* SIEBOLD et ZUCCARINI ; ENDO, *Jap. Jour. Geol. Geogr.*, vol. 11, nos. 3-4, p. 245, pl. 29, figs. 1, 2 ; pl. 30, fig. 5.

1934. *Acer tschonoskii* MAXIMOWICZ ; ENDO, *Jap. Jour. Geol. Geogr.*, vol. 11, nos. 3-4, p. 246, pl. 29, fig. 6.

1940. *Acer micranthum* SIEBOLD et ZUCCARINI ; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 20, fig. 66.

Remarks : A lot of complete leaves are closely related to the extant *Acer micranthum* SIEBOLD et ZUCCARINI and *A. tschonoskii* MAXIMOWICZ. The examined specimens are characterized by the following features: each lobe is acuminate at apex, with a long tip; margin is compoundly double-serrate. These characters show more similar to *A. micranthum* than *A. tschonoskii*.

The living *A. micranthum* SIEBOLD et ZUCCARINI is common in the cool-temperate zone of Japan except for Hokkaido, preferring rather sunny places from the mountain-side to the ridge.

Acer tschonoskii MAXIMOWICZ described by ENDO (1934) has acuminate apex with a long tips in each lobe and may be included into this species.

Collection : SFPG no. 4, GSJ F8040.

Acer miyabei MAXIMOWICZ
Pl. 19, figs. 1, 2

1934. *Acer miyabei* MAXIMOWICZ; ENDO, *Jap. Jour. Geol. Geogr.*, vol. 11, nos. 3-4, p. 244, pl. 32 figs. 1, 4; pl. 35, fig. 1.

1940. *Acer miyabei* MAXIMOWICZ; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 20, fig. 18.

Description: Samara usually medium, oblong in general outline, 2 to 3 cm long and 0.7 to 1.1 cm wide; wing rounded to truncate at apex; outer margin straight to incurved; inner margin nearly straight to gently convex; veins numerous; seeds large and thick, orbiculate; 6 to 10 mm in diamater; angles between outer margin of wing and contact scar of seed 90 to 120 degrees.

Remarks: The present specimens consist of well preserved leaves and samaras. The leaf specimens are characterized by the marginal features such as nearly entire and irregularly undulate with obtusely large dents. These leaves are identical to the living *Acer miyabei* MAXIMOWICZ.

Above mentioned characters of samara suggest that the fossil samaras are related to *Acer miyabei*.

This maple tree is distributed in the cool-temperate zone from Hokkaido to central Honshu, Japan.

Collection: SFPG no. 1, GSJ F8041.

Acer mono MAXIMOWICZ
Pl. 19, figs. 5, 6

1888. *Acer* sp. cf. *A. pictum* THUNBERG; NATHORST, *Pal. Abh.*, vol. 4, no. 3, p. 38, pl. 13, figs. 1, 2.

1934. *Acer pictum* THUNBERG; ENDO, *Jap. Jour. Geol. Geogr.*, vol. 11, nos. 3-4, p. 247, pl. 29, figs. 3, 4, 7-9; pl. 30, fig. 2; pl. 31, figs. 4, 5; pl. 32, figs. 3, 6.

1940. *Acer pictum* THUNBERG; KOIDZUMI, *Acta Phytorax. Geobot.*, vol. 9, no. 1, p. 20, figs. 92, 96.

1954. *Acer pictum* THUNBERG; TAKAHASHI, *Mem. Fac. Sci. Kyushu Univ.*, ser. D, vol. 5, no. 1, p. 60, pl. 7, figs. 3, 4a, b.

1968. *Acer mono* MAXIMOWICZ; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 51, pl. 6, figs. 1, 4, 5.

Remarks: A lot of 5-lobed palmate leaf impressions are referable to *Acer mono* MAXIMOWICZ (Syn. *Acer pictum*) by entire margin, broadly opened sinus and acuminate apex of each lobes. The modern species is widely distributed in the cool-temperate zone of Japan.

Collection: SFPG no. 94, GSJ F8042.

Acer mono var. *glaucum* (KOIDZUMI) SUGIYAMA
Pl. 19, fig. 7

1934. *Acer pictum* var. ?; ENDO, *Jap. Jour. Geol. Geogr.*, vol. 11, nos. 3-4, p. 248, pl. 32. fig. 2.

1940. *Acer latilobum* KOIDZUMI; KOIDZUMI, *Acta Phytorax. Geobot.*, vol. 9, no. 1, p. 19, fig. 93.

Description : Leaves 3-lobed, 5 cm long and 5.5 cm wide (estimated) ; margin entire; lobes ovate-lanceolate with prolong and acuminate apex; base slightly cordate; medial primary vein moderate; lateral lobes making 55 degrees with the medial, secondary veins of the medial lobe 9 subopposite pairs, diverging at angles of 60 degrees, making loops near the margin; tertiary veins reticulate; petiole 1.4 cm long.

Remarks : Three leaf specimens are characterized by foliar shape with three lobes and entire margin. They are referred to the living *Acer mono* var. *glaucum* (KOIDZUMI) SUGIYAMA.

KOIDZUMI (1940) described a leaf impression from the Shiobara group under the name of *Acer latilobum* which is synonymous with this species. A leaf impression discussed by ENDO (1934) as *Acer pictum* var. ? is identical to the present species by trilobed, entire margin and slightly cordate base.

This modern species is distributed in the cool-temperate zone of the Tohoku district of Japan.

Collection : SFPG no. 9.

Acer mono var. *marmoratum* (NICHOLS) HARA

Pl. 19, fig. 4

1971. *Acer mono* forma *dissectum* REHDER; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 34, pl. 7, figs. 7, 8.

Remarks : A single leaf is referred to *Acer mono* var. *marmoratum* (NICHOLS) HARA by its slender 5-lobes with acuminated apex.

ONOE (1971) described a fossil leaf and a samara under the name of *Acer mono* forma dissectum REHDER (Syn. *Acer mono* var. *marmoratum*) from an interglacial age of Pleistocene sediments in Ebino city, Miyazaki Prefecture. The leaf impression is identical with those of the present species.

This maple is endemic to Japan and distributed mainly in the cool- to warm-temperate zones along the Pacific side of Honshu, Shikoku and Kyushu, Japan.

Collection : SFPG no. 12.

Acer nikoense MAXIMOWICZ

Pl. 20, 1-3

1934. *Acer* sp. cf. *A. nikoense* MAXIMOWICZ; ENDO. *Jap. Jour. Geol. Geogr.*, vol. 11, nos. 3-4, p. 243, pl. 35, fig. 2.

Description : Leaves composed compoundly of three leaflets; leaflets variable in shape and size, asymmetrically elliptical to ovate in general outline, acute to obtuse at apex, obliquely rounded at base; undulately dentate with obtuse teeth on the margin excepting for the lower half of blade or basal part; primary vein stout, nearly straight; secondary veins alternate to subopposite, 9 to 13 pairs, irregularly spaced, diverging at angles of 45 to 60 degrees, slightly curving up, entering directly the marginal dents or curving up along the margin and making loops; tertiary veins weakly percurrent; petiolules very short or absent.

Samara large in size, 4.5 cm long and 1.2 cm wide (estimated), wing oblong in shape;

rounded at apex, gently convex on inner margin; seed compressed-globose, 8 mm in diameter; contact line of seed distinct, straight, 1 cm long; angles between contact line and outer margin of wing 37 degrees.

Remarks : The present species is represented by some trifoliate leaves, a lot of detached leaflets and a samara. The leaflets from the Shiobara fossil flora are characterized by undulately dentate margin, obliquely rounded base and irregularly spaced secondaries. They are referred to the living *Acer nikoense* MAXIMOWICZ, which is widely distributed in the cool-temperate zone of Honshu, Shikoku and Kyushu, Japan.

Collection : SFPG no. 95, GSJ F8043, 8044.

Acer palmatum THUNBERG

1934. *Acer eupalmatum* KOIDZUMI; ENDO, *Jap. Jour. Geol. Geogr.*, vol. 11, nos. 3-4, p. 240, pl. 29, fig. 5.

1940. *Acer eupalmatum* KOIDZUMI; KOIDZUMI, *Acta Phytorax. Geobot.*, vol. 9, no. 1, p. 19.

1941. *Acer palmatum* THUNBERG; MIKI, *Jap. Jour. Bot.*, vol. 11, p. 283, figs. 17Ba, b, Ca-d.

1954. *Acer palmatum* THUNBERG; TAKAHASHI, *Mem. Fac. Sci. Kyushu Univ.*, ser. D, vol. 5, no. 1, p. 60, pl. 7, figs. 5, 6, 7a, b.

1971. *Acer palmatum* THUNBERG; OZAKI, *Sci. Rep. Yokohama Nat. Univ.*, Sec. 2, no. 18, pl. 10, fig. 3.

Remarks : Some leaves and samaras of the present species in the Shiobara fossil flora are formerly described as *Acer eupalmatum* (Syn. *Acer palmatum*) by ENDO (1934). The author reinvestigated one of the ENDO's leaf specimen in detail. The leaf is characterized by palmately 5-lobed, lanceolate lobes with doubly serrate margin, and is identical to the extant *Acer palmatum* THUNBERG.

This maple tree is distributed in the warm-temperate zone of Honshu, Shikoku, Kyushu, Japan and extends to Korea and China.

Collection : IGPS Reg. no. 30208.

Acer palmatum var. *amoenum* (CARRIERE) OHWI
Pl. 20, fig. 4

1934. *Acer euseptenlobum* KOIDZUMI; ENDO, *Jap. Jour. Geol. Geogr.*, vol. 11, nos. 3-4, p. 241, pl. 32, figs. 7, 8; pl. 35, fig. 11.

1940. *Acer euseptenlobum* KOIDZUMI; KOIDZUMI, *Acta Phytorax. Geobot.*, vol. 9, no. 1, p. 19.

Remarks : The present species is based on 15 leaves, comprising two almost complete 7-lobed leaves and fragmentary specimens. The fossil leaves are mostly 7 and rarely 5 in palmate lobation with single serrulate margin, deeply cordate at base and long petioles. These characters are identical with the foliage of the living *Acer palmatum* var. *amoenum* (CARRIERE) OHWI, which is widely distributed in the cool- to warm-temperate zones of Japan.

Acer euseptenlobum, described by ENDO (1934) and KOIDZUMI (1940) from the Shiobara fossil flora, is synonymous with the present species.

Collection : SFPG no. 10

Acer rufinerve SIEBOLD et ZUCCARINI
Pl. 20, figs. 6, 7

1934. *Acer rufinerve* SIEBOLD et ZUCCARINI; ENDO, *Jap. Jour. Geol. Geogr.*, vol. 11, nos. 3-4, p. 246, pl. 30, figs. 3, 4; pl. 31, fig. 3.
1937. *Acer rufinerve* SIEBOLD et ZUCCARINI; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 322, fig. 8-O.
1940. *Acer rufinerve* SIEBOLD et ZUCCARINI; KOIDZUMI, *Acta Phytorax. Geobot.*, vol. 9, no. 1, p. 21.
1968. *Acer rufinerve* SIEBOLD et ZUCCARINI; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 52, pl. 8, fig. 2.

Remarks : The present species, represented by numerous leaves and samaras is identical to *Acer rufinerve* SIEBOLD et ZUCCARINI. It is one of the abundant species of the Shiobara fossil flora.

This modern species is found in the cool- to warm-temperate zones of Honshu, Shikoku and Kyushu, Japan.

Collection : SFPG nos 2, 196.

Acer sieboldianum MIQUEL
Pl. 19, fig. 3

1934. *Acer sieboldianum* MIQUEL; ENDO, *Jap. Jour. Geol. Geogr.*, vol. 11, nos. 3-4, p. 243, pl. 31, fig. 6.
1940. *Acer sieboldianum* MIQUEL; KOIDZUMI, *Acta Phytorax. Geobot.*, vol. 9, no. 1, p. 21, figs. 90, 91.
1968. *Acer sieboldianum* MIQUEL; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 52, pl. 6, fig. 3.

Remarks : Only a single detached samara is obtained. It is characterized by the following features: straight to incurved outer margin and gently convexed inner margin; small ellipsoidal seed; angle between outer margin and contact scar 90 degrees. These characters suggest that the examined fossil samara is closely related to *Acer sieboldianum* MIQUEL.

Leaves of the present species from the Shiobara fossil flora were described by ENDO (1934) and KOIDZUMI (1940). They are characterized by small orbiculate in general outline, 9 to 11 palmately lobed, doubly serrate on margin and slightly cordate or rather truncate base.

This maple tree is now living in the cool-temperate zone of Japan.

Collection : SFPG no. 8.

Acer tenuifolium (KOIDZUMI) KOIDZUMI
Pl. 20, fig. 5

Description : Leaf orbicular in general outline, Palmately 9-lobed, 5.8 cm long and 6 cm wide, cordate at base; incisedly and duplicately serrate; principal teeth concave at apical side, while convex at basal side; lobes lanceolate or rhombic-lanceolate, acuminate at apex; each lobe deeply dissected by narrow sinus, two lower pairs of lobes smaller than others,

especially a basal pair smallest; primary vein moderate, palmately emerging from the base, nearly straight, ending in lobe apex; secondary veins weak, 5 to 7 pairs, emerging from the primaries at angles of 55 to 65 degrees, gently curving up, entering principal teeth; tertiary veins obscure; petiole stout, nearly straight, 2.8 cm long.

Remarks : This newly found species from the Shiobara fossil flora is represented by only one but almost complete leaf specimen. It is identical to the living *Acer tenuifolium* (KOIDZUMI) KOIDZUMI by the characters mentioned above.

This maple tree is found in the moist deep mountains of the cool-temperate zone in central and southern Japan.

Collection : SFPG no. 7.

Family Hippocastanaceae

Genus *Aesculus* LINNAEUS

Aesculus turbinata BLUME
Pl. 21, fig. 1; text-fig. 13

Description : Leaflet elliptical-ovate, 14.5 cm long (estimated) and 6.1 cm wide (estimated), apex acute and base obtuse, somewhat oblique; primary vein stout and almost straight from base to apex; secondary veins 14 subopposite pairs, diverging at angles of 40 to 50 degrees, extending almost straight, then curving up along margin; tertiary veins obscure; margin rather sinuate with crenate teeth; petiole missing; texture thin.

Remarks : A single fragmental impression of leaflet appears to represent this species. All the preserved characters are typically *Aesculus turbinata*, especially it has characteristic marginal teeth (text-fig. 13). The living Japanese horse-chestnut tree is distributed in the cool-temperate zone of Japan.

The present species is new record of the occurrence from the Shiobara fossil flora.

Collection : SFPG no. 96.

Family Aquifoliaceae

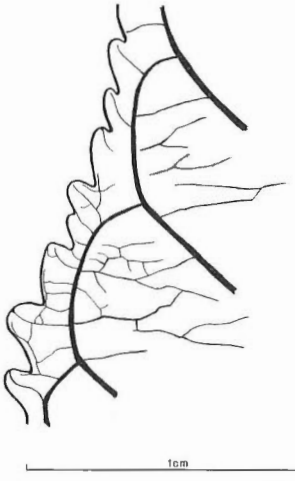
Genus *Ilex* LINNAEUS

Ilex macropoda MIQUEL
Pl. 21, fig. 2

Description : Leaf obovate, 5.4 cm long and 3.2 cm wide; apex acute, base acute; margin crenately serrate by short apical side of the teeth; marginal teeth convex on basal side, straight or rather concave and very short on apical side with attenuate apex; primary vein stout, rather curved; secondary veins 7 subopposite pairs, diverging at angles of 40 to 45 degrees, gently curving up and joining superadjacent veins and making loops near the margin; tertiary, quaternary and higher order veins obscure; petiole stout, more than 1.2 cm long.

Remarks : The leaves are characterized by obovate foliar shape, crenate-like margin and brochidodromous secondary veins. These specimens closely related to the living *Ilex macropoda* growing in the cool- to warm-temperate zones of Japan and extending to Korea and China.

Collection : SFPG no. 143.



Text-fig. 13 Venation characters of fossil *Aesculus turbinata* BLUME. SFPG no. 96, ×4.

Family Celastraceae

Genus *Celastrus* LINNAEUS

Celastrus orbiculatus THUNBERG
Pl. 21, fig. 5

Description : Leaf obovate in general outline, 5.8 cm long and 3.5 cm wide (estimated), broadly cuneate at apex with obtuse tip and acute at base; margin crenately serrate with gland-like tips; venation weak, primary vein sinuous; secondary veins alternately 4 pairs, diverging at angles of 30 to 40 degress, rather zigzaged, curving up and forming angular loops with superadjacent secondaries; tertiary veins irregularly coarsely percurrent; petiole stout, more than 7 mm long.

Remarks : Two fragmentary leaves are examined. The present species is characterized by obovate foliar shape, crenate-like serrate margin with gland-like tips and weak venation. The examined specimens are identical with the modern *Celastrus orbiculatus* THUNBERG which is widely distributed in the cool- to warm-temperate zones of Honshu, Shikoku and Kyushu in Japan and extends to Korea and China.

Collection : SFPG no. 117.

Family Buxaceae

Genus *Buxus* LINNAEUS

Buxus microphylla var. *japonica* (MUELLER)
REHDER et WILSON
Pl. 21, figs. 3, 4

1937. *Buxus japonica* MUELLER; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 320, figs. 7A-B.
1941. *Buxus japonica* MUELLER; MIKI, *Jap. Jour. Bot.*, vol. 11, p. 281, fig. 16 D.

1954. *Buxus japonica* MUELLER; TAKAHASHI, *Mem. Fac. Sci. Kyushu Univ.*, ser. D, vol. 5, no. 1, p. 60, pl. 7, figs. 13 a-g.

1981. *Buxus microphylla* var. *japonica* (MUELLER) REHDER et WILSON; KIMURA et al., *Trans. Proc. Palaeont. Soc. Japan*, N. S., no. 122, p. 96, pl. 9, fig. 13; pl. 11, fig. 1-4; text-figs. 10a-d.

Description : Leaves small, obovate in form, 15 mm long and 8 mm wide, acute at base and emarginate or rarely rounded at apex; margin entire; midvein stout, straight, tapering to the apex; lateral primary veins thinner than the midvein, originating from the petiole, running upward along the margin; secondary veins numerous, diverging at angles of 30 to 60 degrees, dichotomously branching twice or thrice, joining the lateral primaries; tertiary veins slender, diverging at an angle from the secondaries, irregularly ramified; petiole thick, 2 mm long.

Fruit oval, 7 mm long and 6 mm wide; two horn-like appendages at the apex.

Remarks : Description of present species is based on many leaves and a fruit. The leaves of the examined specimens correspond to those of the living *Buxus microphylla* var. *japonica* (MUELLER) REHDER et WILSON by their general outline and venation characters described above.

The fruit with horn-like appendages is also identical to this species.

The examined leaves are indistinguishable from those described by MIKI (1937, 1941), TAKAHASHI (1954) under the name of *Buxus japonica* (Syn. *Buxus microphylla* var. *japonica*) and also described by KIMURA et al. (1981) under the name of *B. microphylla* var. *japonica* (MUELLER) REHDER. et WILSON.

The living species is scatteredly found in central and southern Japan of the warm-temperate zone.

Collection : SFPG no. 198, GSJ F12715

Family Rhamnaceae

Genus *Berchemia* NECKER

Berchemia berchemiaefolia (MAKINO) KOIDZUMI

Pl. 21, fig. 6

Description : Leaves elliptical, 7 to 12 cm long (estimated) and 2.7 to 4.8 cm wide, acute to acuminate at apex and acute to obtuse at base; margin entire or gently undulate; primary vein stout, almost straight, taper to apex, sending off 7 to 10 subopposite secondary veins; secondary veins diverging at angles of 30 to 45 degrees, gently curved and turned up along the margin, camptodromous; tertiary veins closely spaced percurrent, relationship of tertiary veins to midvein perpendicular; quaternary veins forming polygonal meshes; petiole stout, more than 5 mm in length.

Remarks : Fifteen leaves are referred to *Berchemia berchemiaefolia* (MAKINO) KOIDZUMI by the characters described above. This modern species lives in the warm-temperate zone of Honshu, Shikoku and Kyushu, Japan.

Collection : GSJ F12716.

Berchemia racemosa SIEBOLD et ZUCCARINI
Pl. 21, fig. 9

1937. *Berchemia racemosa* SIEBOLD et ZUCCARINI; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 322, figs. 8 F-H.

1940. *Berchemia racemosa* SIEBOLD et ZUCCARINI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 67, pl. 9, figs. 8, 13.

Remarks : The present species is represented by twelve well preserved leaves. They are referred to the living *Berchemia racemosa* SIEBOLD et ZUCCARINI characterized by ovate foliar shape, rather undulate margin, camptodromous secondary veins and perpendicular tertiary veins.

This modern species is widely distributed in the cool- to warm-temperate zones of Japan.

Collection : GSJ F8061.

Family Vitaceae

Genus *Parthenocissus* PLANCHON

Parthenocissus tricuspidata (SIEBOLD et ZUCCARINI) PLANCHON
Pl. 21, fig. 8; pl. 22, fig. 4

Description : Leaves various shape and size, cordate or pentagonal in general outline, mostly 3-lobed in palmate lobation with broadly opened sinus, deeply cordate at base and obtuse or acuminate at apex, 6.5 to 8.5 cm long and 4.8 to 8.8 cm wide; margin coarsely serrate with large acute or obtuse teeth, principal teeth straight to convex at apical side, while convex at basal side; medial primary vein moderate, nearly straight; lateral primaries moderate, slightly curved, making angles of 40 to 50 degrees with the medial, secondary veins 3 to 4 pairs, curving up and ended into large teeth; tertiary veins reticulate; petiole missing.

Remarks : Three leaves are identical to the modern *Parthenocissus tricuspidata* (SIEBOLD et ZUCCARINI) PLANCHON by their foliar shape and small number of large teeth. This deciduous vine is widely distributed in the cool- to warm-temperate zones of Japan, Korea and China.

Collection : SFPG no. 43, GSJ F8049.

Genus *Vitis* LINNAEUS

Vitis coignetiae PULLIAT
Pl. 22, fig. 6

Description : Leaves large size and reniform, broadly to deeply cordate at base and obtuse with short process at apex, 12 cm long (estimated) and 12.5 cm wide; margin irregularly dentate with large obtuse teeth, nearly straight both apical and basal side of teeth, palmately 5-nerved, lower lateral primary veins diverging from the midrib at angles of 30 to 45 degrees, every pirmaries stout and nearly straight; secondary veins of each

primaries 4 to 6 pairs, craspedodromous; tertiary veins irregularly coarsely percurrent; petiole missing.

Remarks : The examined leaves are characterized by large and reniform in foliar shape, palmately 5 primary veins and obtuse dentate margin. The present species is identical to the living *Vitis coignetiae* PULLIAT, which is found in the cool-temperate zone of Hokkaido, Honshu and Shikoku, Japan.

Collection : GSJ F8051.

Vitis flexuosa THUNBERG
Pl. 22, fig. 1.

1940. *Vitis flexuosa* THUNBERG; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 68, pl. 11, figs. 4, 21.

Remarks : The present species, represented by single leaf specimen. It is characterized by deltoid-ovate in foliar shape, nearly truncate at base, palmately 5-primary veins and coarsely triangular teeth on margin. These characters are identical to *Vitis flexuosa* THUNBERG, which is distributed in the warm-temperate zone of Honshu, Shikoku and Kyushu in Japan as well as Korea and China.

Collection : SFPG no. 180

Family Tiliaceae

Genus *Tilia* LINNAEUS

Tilia japonica (MIQUEL) SIMONKAI
Pl. 22, figs. 2, 3; pl. 23, fig. 1

1888. *Tilia* sp. cf. *T. cordata* MILL.; NATHORST, *Pal. Abh.*, vol. 4, no. 3, p. 34, pl. 10, fig. 11.
1940. *Tilia japonica* (MIQUEL) SIMONKAI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 68, pl. 4, fig. 1; pl. 8, figs. 7, 19.
1941. *Tilia japonica* (MIQUEL) SIMONKAI; MIKI, *Jap. Jour. Bot.*, vol. 11, p. 286, figs. 18B, C.
1968. *Tilia japonica* (MIQUEL) SIMONKAI; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 53, pl. 5, figs. 4, 5; pl. 7, figs. 3, 6.

Remarks : A lot of cordate or orbicular leaves are identical with the extant *Tilia japonica* (MIQUEL) SIMONKAI growing in the cool-temperate zone of Japan.

Some leaf fossils identified to this species also resemble the living *Tilia miqueliana* MAXIMOWICZ native to China by their triangularly ovate in foliar shape and obliquely truncate base, but these characters are fall within the variation displayed by the living *Tilia japonica*.

Collection : SFPG no. 199, GSJ F8052, 12717.

Family Haloragaceae

Genus *Myriophyllum* LINNAEUS

Myriophyllum spicatum LINNAEUS
Pl. 22, fig. 5

1940. *Myriophyllum* sp. cf. *M. spicatum* LINNAEUS; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser.,

vol. 21, no. 1, p. 69, pl. 11, fig. 23.

1940. *Myriophyllum verticillatum* LINNAEUS; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 22, figs. 4, 53, 55, 57, 58, 60, 63, 67, 70, 80.

1968. *Myriophyllum* cfr. *spicatum* LINNAEUS; MATSUO, *Ann. Sci. Kanazawa Univ.*, vol. 5, p. 56, pl. 7, fig. 9.

Remarks : Many well preserved leaves are identified to the Genus *Myriophyllum* in their characteristic features, and are referable to *Myriophyllum spicatum* LINNAEUS. The present species has capillary pinnatified leaves decussately arranged to the stem. These characters are common to two extant species *M. verticillatum* LINNAEUS which is distributed in the cool-temperate zone of the Northern Hemisphere, and *M. spicatum* which is widely distributed in the cool-temperate to subtropical zones of the almost whole world. The former's leaves are rather longer than the latter's, and the examined specimens may belong to the latter.

Collection : GSJ F8050.

Family Cornaceae

Genus *Cornus* LINNAEUS

Cornus controversa HEMSLEY

Pl. 23, fig. 5

1940. *Cornus controversa* HEMSLEY; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 70, pl. 10, fig. 2.

1941. *Cornus controversa* HEMSLEY; MIKI, *Jap. Jour. Bot.*, vol. 11, p. 292, fig. 19H

Remarks : The present species is represented by 15 leaves comprising some complete ones. They are identical to the living *Cornus controversa* HEMSLEY by the ovate foliar shape and camptodromous secondary veins.

The modern species is widely distributed in the cool- to warm-temperate zones of Japan, Korea and China.

Collection : SFPG no. 18.

Cornus kousa BUERGER ex MIQUEL

Pl. 23, fig. 6

1940. *Cynoxylon japonica* NAKAI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 70, pl. 9, figs. 17. 19.

1940. *Cynoxylon japonicum* NAKAI; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 23, fig. 40.

1971. *Cornus kousa* BUERGER ex MIQUEL; OZAKI, *Sci. Rep. Yokohama Nat. Univ.*, Sec. 2, no. 18, pl. 10, fig. 4.

Remarks : Leaves of the living *Cornus kousa* BUERGER ex MIQUEL (Syn. *Cynoxylon japonica* NAKAI and *Cynoxylon japonicum* NAKAI) are characterized by oval in foliar shape, acute or abruptly acuminate apex, camptodromous and small number of secondary veins and especially entire but markedly wavy margin. The examined specimens, represented by lots of leaves are identical to the living *Cornus kousa* BUERGER ex MIQUEL.

The living species is growing in the cool-temperate zone of Honshu, Shikoku and

Kyushu in Japan and in Korea.

Collection : GSJ F8053.

Family Araliaceae

Genus *Acanthopanax* MIQUEL

Acanthopanax sciadophylloides FRANCHET et SAVATIER

Pl. 26, fig. 7

Description : Leaves palmately compound, leaflets obovate in general outline, apex obtuse with cuspidate, base cuneate, 9.5 to 12 cm long and 4.8 to 6.5 cm wide; margin coarsely serrate with acute teeth; primary vein moderate, nearly straight; secondary veins 7 subopposite pairs, mixed craspedodromous; tertiary veins irregularly percurrent; ultimate veinlets indistinct; petiolule slender, more than 9 mm long.

Remarks : The examined specimens based on detached leaflets are referred to *Acanthopanax sciadophylloides* FRANCHET et SAVATIER by their obovate in leaflet shape and sporadic minute teeth.

The living species is growing in the cool- to warm-temperate zones of Japan.

Collection : SFPG no. 99.

Genus *Aralia* LINNAEUS

Aralia cordata THUNBERG

Pl. 23, figs. 2, 3

Description : Leaflet ovate, acute at apex, slightly cordate at base, 10 cm long and 7 cm wide; margin irregularly double-serrate, acute teeth; primary vein moderate, taper to a point, mostly straight; secondary veins irregularly spaced, opposite to alternate, gently curving up and making loops with superadjacent secondaries, semicraspedodromous; tertiary and higher order veins obscure; peliolule stout, 6 mm long.

A fragment of fruiting branchlet with one fruit is obtained, 10 pedicels of fruit radially spread, 4 mm long; fruit orbicular, about 2 mm in diameter.

Remarks : The present species consists of a almost complete leaflet and a fragment of fruiting branchlet. These specimens are identical to the living *Aralia cordata* THUNBERG which is widely distributed in the cool- to warm-temperate zones of Japan, Korea and China.

The present species is new record of the occurrence from the Shiobara fossil flora.

Collection : SFPG nos. 147, 150.

Genus *Kalopanax* MIQUEL

Kalopanax septemlobus (THUNBERG) KOIDZUMI

Pl. 24, fig. 1

1940. *Kalopanax septemlobus* (THUNBERG) KOIDZUMI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 69, pl. 12, fig. 7.

1971. *Kalopanax septemlobus* (THUNBERG) KOIDZUMI; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 38, pl. 9, fig. 1.

Remarks : Some well preserved leaves are obtained. They are identical to *Kalopanax*

septemlobus (THUNBERG) KOIDZUMI by their palmately large foliar shape, camptododromous venation and fine serration with acute teeth on he margin. The living species is distributed in the cool- to warm-temperate zones of Japan, Korea and China.

Some leaf impressions of the present species were also described by ONOE (1971) from an interglacial age of Pleistocene sediments in Ebino city, Miyazaki Prefecture and they are identical to the examined species.

Collection : GSJ F7541.

Family Clethraceae

Genus *Clethra* LINNAEUS

Clethra barbinervis SIEBOLD et ZUCCARINI

Pl. 26, figs. 3, 4

1940. *Clethra barbinervis,* SIEBOLD et ZUCCARINI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 71, pl. 9, figs. 3, 16.

1940. *Clethra barbinervis* SIEBOLD et ZUCCARINI; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 23.

Remarks : Many well preserved leaves are identical with thc existing species by obovate in foliar shape, camptodromous secondary veins and fine serration with acute teeth on margin.

ENDO (1940) described also many leaves and a fruit specimens of the present species from the Shiobara fossil flora.

The living, *Clethra barbinervis* is widely distributed in the cool- to warm-temperate zones of Japan and Korea.

Collection : GSJ F8060, 8079.

Family Ericaceae

Genus *Enkianthus* LOUREIRO

Enkianthus campanulatus (MIQUEL) NICHOLS

Pl. 23, fig. 4

1940. *Meisteria campanulata* NAKAI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 72, pl. 11, figs. 6, 20.

Remarks : A lot of leaves are referred to *Enkianthus campanulatus* (MIQUEL) NICHOLS by their obovate in foliar shape, obtuse apex, cuneate base and very fine serrulate margin with attenuate teeth. ENDO (1940) described many leaves under the name of *Meisteria campanulata* NAKAI (Syn. *Enkianthus campanulatus*) from the Shiobara fossil flora.

The living species is growing in the cool-temperate zone of southern Hokkaido and Honshu, Japan.

Collection : GSJ F8057.

Genus *Lyonia* NUTTALL

Lyonia ovalifolia var. *elliptica* (SIEBOLD et ZUCCARINI) HANDEL-MAZZETTI

Pl. 24, fig. 4

1940. *Xolisma elliptica* NAKAI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 73, pl. 10, figs. 16, 19.

1940. *Xolisma elliptica* NAKAI; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 23, fig. 73.

Description : Leaves variable shape and size, ovate to oblong-ovate in general outline, acute to mucronate at apex and obtuse to slightly cordate at base, 4.5 to 10 cm long and 2.7 to 5.5 cm wide; margin entire or rather undulate; primary vein moderate, slightly curved; secondary veins variable as to spacing and angle of divergence, camptodromous; tertiary veins obscure; petiole 2 to 7 mm long.

Remarks : The examined leaves are identical to those of the living *Lyonia ovalifolia* var. *elliptica* by the above mentioned characters. ENDO (1940) and KOIDZUMI (1940) studied leaves of *Xolisma elliptica* NAKAI, which is the synonym of the present species.

The extant species is widely distributed in the warm-temperate zone of Honshu, Shikoku and Kyushu, Japan.

Collection : GSJ F8056.

Genus *Rhododendron* LINNAEUS

Rhododendron degronianum CARRIERE

Pl. 25, fig. 1

1940. *Rhododendron degronianum* forma *spontaneum* NAKAI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 71, pl. 5, figs. 2, 4.

Description : Leaves oblong to oblanceolate in general outline, acute or cuspidate at apex and cuneate to broadly cuneate at base, 6 to 11 cm long and 1.5 to 3 cm wide; margin entire; primary vein stout and straight; secondary veins weak and obscure; texture thick; petiole stout, more then 1 cm long.

Remarks : a number of well-preserved leaves are referred to *Rhododendron degronianum* CARRIERE by their oblong to oblanceolate in foliar shape, weak secondary veins, cuneate base and especially thick-coriaceous texture.

Some leaves, once established as *Rhododendron degronianum* forma *spontaneum* from the Shiobara fossil flora (ENDO, 1940), is probably referred to the present species by its foliar shape.

The living species is distributed in the cool-temperate zone of northern and central Honshu, often dominant in the shrub-layer of coniferous forests and also common on sunny ridges.

Collection : GSJ F7556.

Rhododendron kaempferi PLANCHON

Pl. 24, figs. 2, 3

1940. *Rhododendron kaempferi* PLANCHON; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21,

no. 1, p. 72, pl. 7, fig. 18; pl. 11, fig. 18.

Remarks : The present species is not rare in the Shiobara fossil flora. The examined leaf specimens have the same aspect to the leaves of the living *Rhododendron kaempferi* such as hairy margin and glandular pointed tip.

The living species is widely distributed in the cool- to warm-temperate zones from Hokkaido to Kyushu, Japan.

Collection : GSJ F8054, 8055.

Rhododendron quinquefolium BISSET et MOORE
Pl. 23, fig. 7

1971. *Rhododendron quinquefolium* BISSET et MOORE; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 39, pl. 8, fig. 6.

Remarks : A number of well preserved leaves are examined. These leaves are identical to those of the modern *Rhododendron quinquefolium* BISSET et MOORE by the rhomboidal obovate in foliar shape and gland-like pointed tip.

The modern species is growing in the cool-temperate zone in the coastal region of the Pacific Ocean side of Honshu and Shikoku, Japan.

Collection : GSJ F8058.

Rhododendron wadanum MAKINO
Pl. 24, fig. 5

1940. *Rhododendron wadanum* MAKINO; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 23.
1940. *Rhododendron dilatatum* MIQUEL; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 72. pl. 10, figs. 18, 21.

Description : Leaves rhomboidal or broadly ovate in shape, 2.5 to 5.5 cm long and 1.8 to 4.1 cm wide; base broadly cuneate, apex acute or mucronate; primary vein thick below, gradually thin toward the apex, straight or rather sinuous; secondary veins slender, 4 to 5 pairs, subopposite to alternate, leaving the primary vein at the angles upper more acute than lower, basal two pairs diverging at angles of 55 to 65 degrees, upper pairs diverging at angles of 35 to 45 degrees, all secondaries curving upwards and making loops, camptodromous; tertiary veins forming fine areolation; margin entire; petiole thick, 4 mm long.

Remarks : Abundant rhomboidal fossil leaves are similar to *Rhododendron wadanum* and *R. dilatatum* in general appearance, and more closely resemble those of the former in the characters of petiole. The living *Rhododendron wadanum* has short petiole (2 to 6 mm long) with hairs on it, while *Rhododendron dilatatum* has long one (8 to 15 mm long) without hairs. The petioles of all examined specimens are in less than 4 mm in length. Some specimens are impressed hairs on the petioles.

Two leaves, previously described under the name of *Rhododendron dilatatum* from the Shiobara fossil flora by ENDO (1940, pl. 10, figs. 18, 21) have so short petioles that they may be included in the present species.

The living *Rhododendron wadanum* MAKINO is distributed in the cool-temperate zone along the Pacific Ocean side of Honshu, Japan.

Collection : GSJ F7557.

Genus *Tripetaleia* SIEBOLD et ZUCCARINI

Tripetaleia paniculata var. *latifolia* MAXIMOWICZ
Pl. 25, fig. 9

1940. *Tripetaleia paniculata* var. *latifolia* MAXIMOWICZ; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1. p. 73, pl. 6, fig. 10; pl. 11, fig. 20.

Remarks: Some well preserved leaves are examined. They are identical with the living *Tripetaleia paniculata* var. *latifolia* MAXIMOWICZ by narrow elliptic in foliar shape, decurrent base, acuminate apex and camptodromous secondary veins which resemble that of the genus *Cinnamomum*.

The living species is growing in the cool-temperate zone of Japan.

Collection: SFPG no. 123.

Family Styracaceae

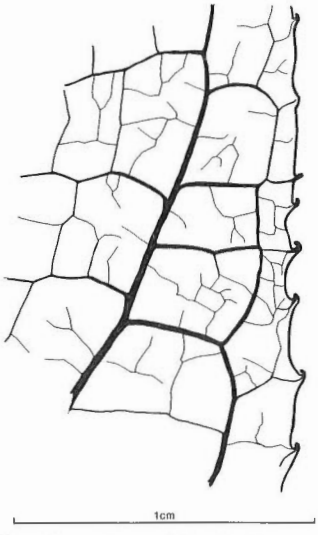
Genus *Pterostyrax* SIEBOLD et ZUCCARINI

Pterostyrax hispida SIEBOLD et ZUCCARINI
Pl. 25, figs. 3, 5; text-fig. 14

Description: Leaf imcomplete, upper one third absent, 10 cm long (estimated) and 6.2 cm wide (estimated) ; apex absent, base rounded, margin serrulate with bristly teeth terminated with glands; primary vein moderate, slightly arched; secondary veins irregularly spaced, 12 pairs (estimated), alternate to subopposite, diverging at angles of 45 to 65 degrees, nearly straight or gently curving up and making loops near the margin; tertiary veins irregularly percurrent; petiole 1.2 cm long.

Fruits lanceolate, acuminate at tip and cuneate at base; 1.4 mm long and 3 mm wide.

Remarks: The present species is based on a fragmentary leaf and a cluster of fruit.



Text-fig. 14 Venation characters of fossil *Pterostyrax hispida* SIEBOLD et ZUCCARINI. SFPG no. 105, ×4.

The leaf is characterized by bristly toothed margin with glands on tip of the teeth as shown in text-fig. 14 and identical to the living *Pterostyrax hispida* SIEBOLD et ZUCCARINI. The fruit is also identical to the present species by their outline and size.

The living *Pterostyrax hispida* SIEBOLD et ZUCCARINI is widely found on such sunny and mesic sites as along nountain-streams in the cool-temperate zone of Honshu, Shikoku and Kyushu, Japan.

Collection : SFPG nos. 105, 159.

Genus *Styrax* LINNAEUS

Styrax japonica SIEBOLD et ZUCCARINI

Pl. 25, fig. 4; text-fig. 15

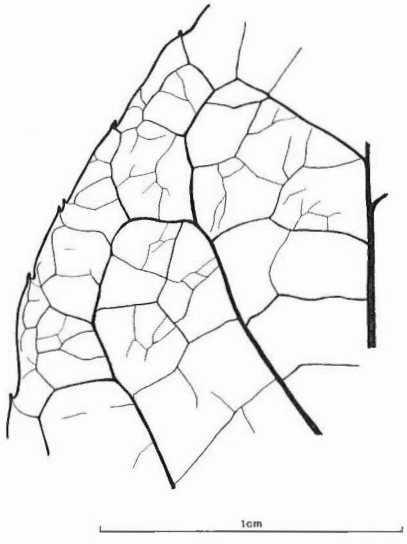
1937. *Styrax japonica* SIEBOLD et ZUCCARINI; MIKI, *Jap. Jour. Bot.*, vol. 8, p. 327, figs. 9 N-O.

Description : Leaves obovate in general outline, 5 to 6.5 cm long and 2.6 to 2.8 cm wide, acute to acuminate at apex and cuneate at base; primary vein moderate slightly arched; secondary veins slender, 4 to 5 subopposite to alternate pairs, irregularly spaced, diverging at angles of 30 to 45 degrees, gently curving up and forming distinct loops, brochidodromous; tertiary veins forming a coarse polygonal network; margin irregularly spaced serrate with acute teeth.

Remarks : Several leaves are referred to *Styrax japonica* SIEBOLD et ZUCCARINI by the irregularly spaced serrate margin with acute teeth (text-fig. 15), obovate foliar shape and brochidodromous venation.

The living species is growing from the cool-temperate to subtropical zones of Japan, Korea and China.

Collection : SFPG no. 106.



Text-fig. 15 Venation characters of fossil *Styrax japonica* SIEBOLD et ZUCCARINI. SFPG no. 106, ×4.

Styrax obassia SIEBOLD et ZUCCARINI
Pl. 25, fig. 2

1940. *Styrax obassia* SIEBOLD et ZUCCARINI; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 74, pl. 9, fig. 12; pl. 11, fig. 28.

Description : Leaf oval, both tip and base missing; more than 9 cm long and 5.6cm wide; margin entire with sporadic minute teeth only on the upper half of the blade; primary vein moderate, straight, tapered at apice; secondary veins irregularly spaced, 6 or 7 alternate pairs, gently curving up and making distinct loops, brochidodromous, diverging at angles of 30 to 60 degrees; tertiary veins coarsely irregularly percurrent; quaternary veins forming a polygonal mesh; petiole absent.

Remarks : The examined specimen is attached to *Styrax obassia* SIEBOLD et ZUCCARINI with some hesitation, because only one incomplete leaf has been collected. The specimen is characterized by oval foliar shape, irregularly spaced and brochidodromous secondaries and marginal minute teeth on the upper half of the blade. These characters may be referred to the living *Styrax obassia* SIEBOLD et ZUCCARINI which is distributed in the cool-temperate zone of Japan, Korea and China.

Collection : SFPG no. 107.

Family Oleaceae

Genus *Fraxinus* LINNAEUS

Fraxinus lanuginosa KOIDZUMI
Pl. 25, fig. 6-8

1971. *Fraxinus lanuginosa* KOIDZUMI; ONOE, *Rep. Geol. Surv. Jap.*, no. 241, p. 40, pl. 9, figs. 5-8.

Description : Leaf odd-pinnate with five leaflets; leaflets oblong to elliptical-ovate in general outline, 2.5 to 6.2 cm long and 1.4 to 2.3 cm wide, apex acuminate, the terminal leaflet relatively symmetrically cuneate base, and the lateral leaflets asymmetrically rounded base; margin mostly single serrate, marginal teeth straight to concave on apical side and convex on basal side, acute at both sinus and tooth apex; primary vein moderate to stout, straight; secondary veins 6 to 9 pairs, opposite to alternate, leaving the primaries at the angles of 50 to 60 degrees, curving upwards and making loops, brochidodromous; tertiary veins obscure; only terminal leaflet has petiole, 5 mm long.

Fruit linear in outline, with short pedicel, 1.7 to 2.2 cm long and 3 to 4 mm wide; wing oblong, apparently round at the tip, attached at the end of seed, nerves thin, numerous, subparallel to long axis of samara; seed lanceolate, 5 to 8 mm long and 1.5 to 2.5 mm wide.

Remarks : A single leaf with five leaflets, lots of detached leaflets and some fruits are assigned to *Fraxinus lanuginosa* KOIDZUMI by the above decribed characters.

The living species is widely distributed in the cool-temperate zone of Japan and Korea.

Collection : SFPG nos. 108, 201, GSJ F8059.

Genus *Ligustrum* LINNAEUS

Ligustrum tschonoskii DECAISNE
Pl. 26, fig. 5

1940. *Ligustrum yezoense* NAKAI; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 23, fig. 71.

Description : Leaf small, narrow elliptic, 4.4 cm long and 1.6 cm wide; apex and base acute; margin entire; primary vein moderate, taper to a tip, nearly straight; secondary veins slender, oppositely 8 pairs, diverging at angles of 40 to 45 degrees, gently curving upward and making loops, brochidodromous; tertiary veins missing; petiole 6 mm long.

Remarks : This perfect leaf has small-sized lamina, narrow elliptic foliar shape, slender and brochidodromous secondary veins. These characters in appearance reveal that it belongs to the species of *Ligustrum*, and is similar to the *Ligustrum tschonoskii* growing in the cool-temperate zone of Japan.

Ligustrum yezoense NAKAI, described by KOIDZUMI (1940) from the Shiobara fossil flora is synonym of the present species.

Collection : SFPG no. 152.

Family Rubiaceae

Genus *Galium* LINNAEUS

Galium kinuta NAKAI et HARA
Pl. 26, figs. 1, 2

Description : Leaves verticillate arrangement, four leaves attached oppositely to the stem, leaves lanceolate, 2.5 cm long and 0.8 cm wide, attenuate at apex and broadly cuneate at base; margin entire; three primary veins originating at the base of the leaf, midvein nearly straight, lateral veins running upward between midvein and margin and ending at apex; secondary veins missing; petiole absent.

Remarks : The present species is represented by three specimens impressed three or four leaves attached to the stems. They are identical to the living *Galium kinuta* NAKAI et HARA by the characters described above. The examined species is a new discovery from the Shiobara fossil flora.

The modern species is growing in the cool-temperate zone of Honshu, Shikoku and Kyushu, Japan.

Collection : SFPG nos. 114, 202.

Family Caprifoliaceae

Genus *Viburnum* LINNAEUS

Viburnum dilatatum THUNBERG
Pl. 27, figs. 1, 6

Description : Leaves variable size and shape, broadly obovate to orbicular in general outline, obtuse to mucronate at apex and broadly cuneate to rounded at base, 4.6 to 8 cm long and 4 to 6 cm wide; margin coarsely dentate, marginal teeth obtuse; primary vein moderate, rather sinuous; secondary veins 5 to 7 subopposite pairs, almost straight, diverging at angles of 35 to 40 degrees, craspedodromous; tertiary veins branching from the lowest

secondaries giving off straightly to the margin and entering large teeth, while the tertiary veins in intersecondary spaces fine percurrent; petiole more than 5 mm long.

Fruit oval, mucronate at apex and obtuse at base, 5 to 6 mm long and 3 to 4 mm wide; peduncle 4 to 8 mm long.

Remarks: Several well preserved leaves are identical to *Viburnum dilatatum* THUNBERG by the marginal features of coarsely dentate with obtuse teeth and acute angles at the divergence of secondary veins. Fruiting shoot is similar to that of the genus *Viburnum* by the shape and arrangement of fruits. The size of fruits more resemble the present species.

The living species is widely distributed in the cool- to warm-temperate zones of Japan, Korea and China.

Collection: SFPG no. 206, GSJ F8081.

Viburnum furcatum BLUME
Pl. 26, fig. 6

1940. *Viburnum furcatum* BLUME; ENDO, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 21, no. 1, p. 75, pl. 11, fig. 26; pl. 12, figs. 1, 4a, 8.

1940. *Viburnum furcatum* BLUME; KOIDZUMI, *Acta Phytotax. Geobot.*, vol. 9, no. 1, p. 24, fig. 34.

Description: Leaves variable size and shape, normaly orbicular or reniform in general outline, rounded or cuspidate at apex and obtuse to cordate at base, 6 to 12 cm long and 3.2 to 12 cm wide; margin doubly serrulate with dull point teeth; primary vein moderate, slightly curved; secondary veins about 10 pairs, subopposite to alternate, dichotomously branching once or twice and entering large teeth, craspedodromous; tertiary veins fine percurrent; quaternary and higher order veins obscure; petiole stout, more than 1 cm long.

Remarks: A lot of leaves are identical to *Viburnum furcatum* BLUME by reniform foliar shape, dichotomously branching secondaries and doubly serrulate margin with dull point teeth.

The living species is widely distributed in the cool-temperate zone from Hokkaido to Kyushu, Japan.

Collection: GSJ F7532.

Viburnum phlebotrichum SIEBOLD et ZUCCARINI
Pl. 27, fig. 3

Description: Leaves ovate to oblong-ovate in general outline, 6.2 cm long and 2.6 cm wide, acuminate at apex and broadly cuneate at base; margin dentate; primary vein moderate, nearly straight, secondary veins 7 opposite to subopposite pairs, diverging at angles of 25 to 35 degrees, running straight into marginal teeth; tertiary veins near the margin sending off from the secondaries and entering marginal teeth, tertiaries among the inter secondaries percurrent; quaternary veins forming a polygonal meshes; petiole stout 2 cm long.

Remarks: This newly found species from the Shiobara fossil flora is based on the small material, comprising two nearly complete leaves and a fragment. The examined speciment

are identical to *Viburnum phlebotrichum* SIEBOLD et ZUCCARINI by ovate foliar shape, dentate margin and venation characters described above.

The modern species is distributed in the cool-temperate zone of Honshu, Shikoku and Kyushu, Japan.

Collection : SFPG no. 109.

Viburnum sieboldii MIQUEL
Pl. 27, fig. 5

Description : Leaves obovate-oblong in general outline, abruptly acute or rounded at apex and cuneate at base, 11.5 cm long and 3.9 cm wide; margin entire at basal half or one third of the blade and serrate at apical side of the blade, marginal teeth acute tips, straight on the apical side and rather convex on the basal side; primary vein stout, slightly curved, taper to a point; secondary veins almost parallel, 10 to 15 subopposite pairs, gently curving up and making loops; tertiary veins fine percurrent; petiole thick, sulcated above and dilated at base, 1.5 cm long.

Remarks : Many well preserved leaf impressions are indubitably referred to *Viburnum sieboldii* MIQUEL in their marginal feature, foliar shape and venation charactors. The present species is newly discovered from the Shiobara fossil flora.

The living species is growing in the cool- to warm-temperate zones from central Honshu to Kyushu, Japan.

Collection : GSJ F7558.

Viburnum wrightii MIQUEL
Pl. 27, fig. 4

Description : Leaves broadly obovate to orbicular in general outline, acute apex with elongate-acuminate tip and rounded to broadly cuneate at base, 9 cm long and 6 cm wide; margin coarsely dentate, marginal teeth deltoid, straight or rather concave on the apical side and straight or rather convex on the basal side; primary vein moderate, slightly arcuate; secondary veins nearly straight, 9 subopposite to alternate pairs, diverging at angles of 30 to 40 degrees, craspedodromous; tertiary veins near the margin branching off and ending in marginal teeth, tertiaries among intersecondary spaces fine percurrent; petiole stout more than 1 cm long.

Remarks : These leaves are referred to *Viburnum* in their marginal and venation characters. They are identical to those of the living *V. wrightii* MIQUEL in their deltoid marginal teeth and broadly obovate in foliar shape.

The present species in now growing in the cool-temperate zone of Japan, Korea and China.

Collection : SFPG no. 20.

Family Compositae

Genus *Artemisia* LINNAEUS

Artemisia princeps PAMPANINI
Pl. 27, figs. 7, 8

Description : Leaves pinnately incised, 10 cm long (estimated) and 6.5 cm wide, each lobes separated by acuminate sinuses; lobes lanceolate, acuminate at apex; primary vein moderate, nearly straight; secondary veins 2 or 3 subopposite pairs, running off in the center of each lobes, ending into apex of the lobes; petiole missing.

Remarks : These fossil leaves are identical to *Artemisia* in their general appearance, and are referred to the living *A. princeps* PAMPANINI by their foliar shape and size.

This perennial grass is widely distributed in the cool- to warm-temperate zones of Honshu, Shikoku and Kyushu in Japan as well as in Korea.

Collection : SFPG nos. 110, 156.

Genus *Chrysanthemum* LINNAEUS

Chrysanthemum sp. cf. *C. makinoi* MATSUMURA et NAKAI
Pl. 27, fig. 2

Description : Leaf trilobed, orbicular in general outline, 3.5 cm long and 2.5 cm wide; medial lobe deltoid, with a pair of small lobes; apice of each lobe acute; base cuneate with the blade decurrent along the petiole; margin irregularly doubly serrate. primary vein thin, lateral primaries leaving midrib suprabasal, at angles of about 40 degrees, dichotomously branching once, running into the larger teeth; secondary veins obscure, one or two pairs on each primaries; veinlets finely reticulate; petiole absent.

Remarks : A single leaf impression represents leaves of the Genus *Chrysanthemum* in its peculiar shape and margin. It is identical to *Chrysanthemum makinoi* which is now widely distributed in the cool- to warm-temperate zones of Honshu, Shikoku and Kyushu, Japan.

Collection : SFPG no. 148.

Genus *Saussurea* DE CANDOLLE

Saussurea sp.
Pl. 28, fig. 1

Description : Leaf deltoid-ovate in general outline, acute at apex and deeply cordate at base, 8.5 cm long (estimated) and 5.4 cm wide; margin dentate, marginal teeth triangular, straight or rather concave on both the apical and basal side; primary vein moderate, rather sinuous; secondary veins 5 opposite pairs, brochidodromous, making angular loops; tertiary veins in the marginal area extending from the marginal teeth, tertiaries in the intersecondary spaces random reticulate; quaternary veins finely reticulate; petiole missing.

Remarks : Only one leaf impression has several characters that indicate a close relationship to *Saussurea*: deltoid-ovate foliar shape, marginal serration and angular loops of secondaries. The leaf is similar to the extant *S. nipponica* MIQUEL and *S. nikoensis* FRANCHET et SAVATIER, but the examined specimen is incomplete to warrant assigning a specific name.

Collection : SFPG no. 151.

Family Potamogetonaceae

Genus *Potamogeton* LINNAEUS

Potamogeton maackianus A. BENNETT
Pl. 28, figs. 2, 3

Description : Stem 1 to 1.5 mm wide, extending zigzag; leaves extending from the bending portion of the stem, alternate, lenear, 2 to 4 cm long and 1 to 2 mm wide, base slightly clasping the stem and apex rounded; primary vein thin but distinct; secondary veins running parallel with the primaries, faint; margin entire.

Remarks : These specimens are identical to submarshed plant of the living *Potamogeton maackianus* A. BENNETT by zigzaged stem and linear leaves clasping the stem. This aquatic herb is widely distributed in the cool- to warm-temperate zones of Japan, Korea and China.

Collection : SFPG no. 111, GSJ F8080.

Potamogeton perfoliatus LINNAEUS
Pl. 28, fig. 6

Description : Leaves alternately attached to the stem, oblong-ovate, apex missing, base cordate, clasping the stem, about 4 cm long and 1.5 cm wide.

Remarks : Only two incomplete specimens are identical to the living *Potamogeton perfoliatus* LINNAEUS by their following features: leaves remotely alternately arranged, the basal part of leaves clasp the stem and campylodromous venation on the blade.

This pondweed is widely distributed from cool-temperate to subtropical zones of the world. The present species is newly found fossil from Shiobara fossil flora.

Collection : SFPG no. 112.

Family Liliaceae

Liliaceae gen. et sp. indet.
Pl. 28, fig. 5

Description : Leaf narrowly oblong, apex acuminate and base cuneate with leaf sheath, 8.2 cm long (estimated) and 1.8 cm wide; margin entire; venation parallelodromous, 3 primary veins rather strong than others; leaf sheath more than 3.2 cm long and 4.5 mm wide, some vertical venation on it.

Remarks : A single specimen represent leaf of the Liliaceae in its foliar shape, venation character and leaf sheath.

Collection : SFPG no. 135.

Family Gramineae

Genus *Sasa* MAKINO et SHIBATA

Sasa sp. cf. *S. kurilensis* (RUPRECT) MAKINO et SHIBATA

Pl. 28, fig. 8

Remarks : The present leaf is referable to *Sasa* by its shape and parallelodromous venation. The leaf is supposed to be oblong-lanceolate foliar shape, 12 cm long, 2.3 cm wide and acuminate apex. It has strong midrib and six pairs of clear lateral veins. These characters suggest the living *Sasa kurilensis* (RUPRECT) MAKINO et SHIBATA, which is widely distributed in the cool-temperate zone of Hokkaido and Japan Sea side slope of Honshu, Japan.

Collection : SFPG no. 204.

Sasa sp. cf. *S. palmata* (BEAN) NAKAI

Pl. 28, fig. 7

Remarks : A single fragmentary leaf is identified to *Sasa* by its parallelodromous venation. The present specimen has a strong midvein and 9 or 10 pairs of obscure lateral veins and it is supposed more than 15 cm in length and 5 cm in width of the blade. The examined leaf is clearly different from *Sasa kurilensis* (RUPRECT) MAKINO et SHIBATA by its foliar shape, size and venation characters. The present specimen is rather similar to *Sasa palmata* (BEAN) NAKAI, which is widely distributed in the cool- to warm-temperate zones of Japan Sea side area of Hokkaido, Honshu and rarely in Kyushu, Japan.

Collection : SFPG no. 161.

Gramineae gen. et sp. indet.

Pl. 28, fig. 4

Remarks : A single fragmentary stem is referable to the Gramineae in tis fine vertical stripes and bending stem at node. The examined specimen is too incomplete to give specific name.

Collection : SFPG no. 136.

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Paleoenvironmental analysis based on the Pleistocene Shiobara flora in the Shiobara volcanic basin, central Japan

By

Toru ONOE

Abstract

General remarks

This report deals with the paleoclimate of the Pleistocene age in the Shiobara volcanic basin (139.8°E, 37°N), Tochigi Prefecture, central Japan, by means of systematic description on the Shiobara flora which commonly occurs in the field.

The flora, being well preserved within fine laminated lake sediments, has been widely accepted to be of glacial age in the Pleistocene period. On the way of his descriptive work, however, the author encountered several fundamental questions against such a concept on the flora. Thereafter, precise research on 11,494 individual specimens in the flora does not merely indicate cooler climate, but also represents moderate to slightly warmer temperature. The geologic age of fossil-bearing laminated mudstone is indirectly determined to 0.3 Ma in relation to the K-Ar whole-rock age of overlying and intercalated lavaflows from the Takahara Volcano.

Present environment

The Shiobara volcanic basin is located at the northern foot of Takahara Volcano. The topography of the basin has been still preserved as it was in the middle Pleistocene period.

The basin measures about 5 km × 2 km. The Hoki River runs through the central part of basin from the west to the east, cutting through alluvial plains and hills ranging about 550 to 750 m in their altitude. The margin of the basin is limited by ridge of 1,000 to 1,700 m in heights.

On the eastern side of the central divide of northern Honshu, the Shiobara volcanic basin belongs to the Pacific-coastal climatic region. Annual mean temperature and precipitation in the basin are 10.5°C and 1,706 mm, respectively. Present vegetation in the basin and neiboring area is mainly cool-temperate forest, principally represented by broad-leaved trees such as *Fagus crenata*.

Geology

Stratigraphical succession in and around the Shiobara basin is briefly described below.

The basement rocks of the basin are pre-Tertiary chert and sandstone-slate (Kawaji Group), and Miocene volcaniclastic rocks (so-called "green-tuff").

The Shiobara Group, Pleistocene lake sediments composed of conglomerate, sandstone and mudstone, unconformably overlies the basement rocks. The group is overlain by lavaflows of the Takahara Volcano, terrace gravel beds, altered volcanic ash layers etc. Total thickness of the group is about 400 m.

Conglomerate and sandstone represent the marginal facies in the group, whereas fossil-bearing mudstone is dominant in the central part of the basin.

Description of the Shiobara flora

The Shiobara flora is composed of 51 families, 104 genera and 171 species of macrofossils. The most of materials are foliage. Reproductive organs, such as seeds, fruits and flowers are also found.

The largest family in the flora is the Rosaceae with 13 genera and 23 species; followings are the Betulaceae with 4 genera and 16 species, the Aceraceae with 1 genus and 14 species, the Saxifragaceae with 8 genera and 11 species, the Ericaceae with 4 genera and 7 species and the Fagaceae with 3 genera and 6 species.

In number, *Fagus crenata* is the most predominant species which occupies up to 13.3% of the total specimens. It is followed by *Fagus japonica* (11.3%), *Castanea crenata* (6.2%), *Betula schmidtii* (5.7%), *Quercus mongolica* var. *grosseserrata* (5.3%). Such an assemblage bears a close resemblance to that of the present vegetation in Japan and its neibouring countries, where cool-temperate climates are dominant. In addition to this, the author revealed that the Shiobara flora also contains the species of transitional facies towards relatively warm-temperate forest zone, which is so-called "the hemitemperate zone forest". The principal species in this transitional zone are *Fagus japonica, Castanea crenata, Carpinus tschonoskii, Quercus serrata* etc., Moreover, some warm-temperate aspects such as *Buxus microphylla* var. *japonica, Berchemia berchemiaefolia* and *Lyonia ovalifolia* var. *elliptica* are included in this flora.

13 specimens for pollen and spore analysis has been chosen among mudstone samples in which plenty of studied macrofossils have been contained. Identified microfossils have been classified into 50 types, namely 8 conifers (*Abies, Picea, Pinus, Cryptomeria* etc.), 35 broad-leaved trees (*Juglans, Alnus, Betula, Fagus* etc.) and 7 herbs (*Artemisia,* Gramineae, ferns etc.).

Discussion and conclusion

Through the all species of macrofossils and microfossils, anemophilous plants are generally in common in both categories of families and genera, whereas entomophilous plants are principally found in the accumulation of macrofossils, but a few in of micro ones. In case of terrestrial herbs, macrofossils are scarce in number, in contrast that microfossils are predominant. Such difference of distribution pattern on macrofossils and microfossils among anemophilous plants, entomophilous plants and herbs, could be chiefly caused by the factors of productivity, resistivity against decomposition and scattering method of the leaves and pollens.

In conclusion, main features of the Shiobara flora are almost the same to the vegetation as of today. It means that the climatic and environmental conditions around the Paleo-Shiobara Lake should be principally similar to the present ones. As a corollary, the author could reconfirm no evidence that the flora might have grown under the cooler circumstance representing a glacial period as once reported.

PLATES

AND

EXPLANATIONS

(with 31 plates)

Explanation of Plate 1
(All figures in natural size)

Figs. 1, 2. *Davallia mariesii* MOORE (シノブ). SFPG nos. 163 (fig. 1), 172 (fig. 2).

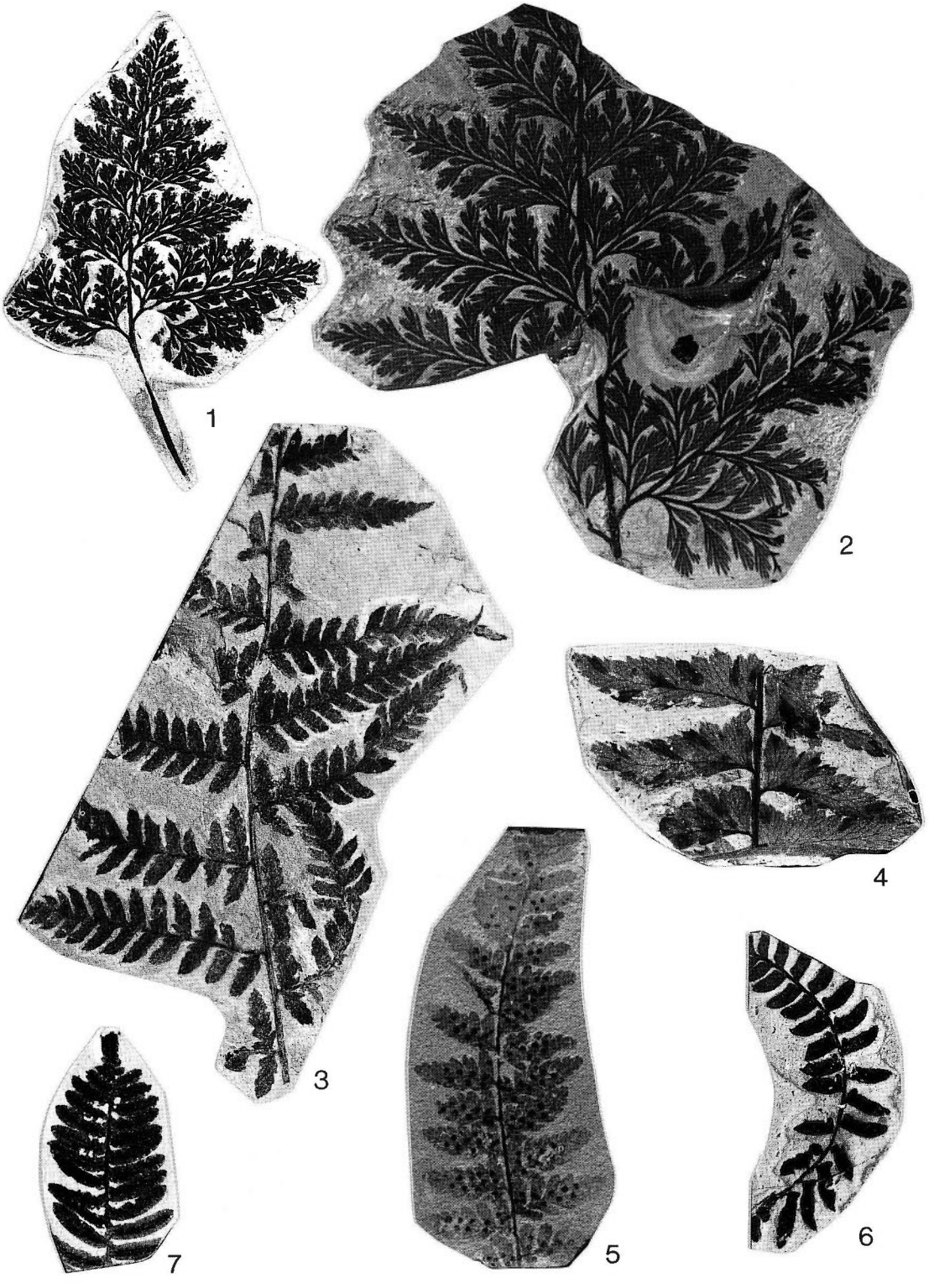
Fig. 3. *Athyrium yokoscense* (FRANCHET et SAVATIER) CHRIST (ヘビノネゴザ). SFPG no. 164.

Fig. 4. *Polystichum tripteron* (KUNZE) PRESL (ジュウモンジシダ). SFPG no. 165.

Fig. 5. *Woodsia manchuriensis* HOOKER (フクロシダ). SFPG no. 166.

Fig. 6. *Woodsia polystichoides* EATON (イワデンダ). SFPG no. 30.

Fig. 7. *Blechnum amabile* MAKINO (オサシダ). SFPG no. 167.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Explanation of Plate 2
(All figures in natural size)

Figs. 1, 2. *Abies firma* SIEBOLD et ZUCCARINI (モミ). KYOTO UNIV. (fig. 1), SFPG no. 158 (fig. 2).

Figs. 3-5. *Larix leptolepis* (SIEBOLD et ZUCCARINI) GORDON (カラマツ). SFPG nos. 3 (fig. 3), 6 (fig. 4), 21 (fig. 5).

Figs. 6-8. *Picea polita* (SIEBOLD et ZUCCARINI) CARRIERE (ハリモミ). SFPG nos. 168 (fig. 6), 169 (fig. 7), 50 (fig. 8).

Figs. 9, 10. *Pinus parviflora* SIEBOLD et ZUCCARINI (ヒメコマツ). GSJ F8015 (fig. 9), SFPG no. 41 (fig. 10).

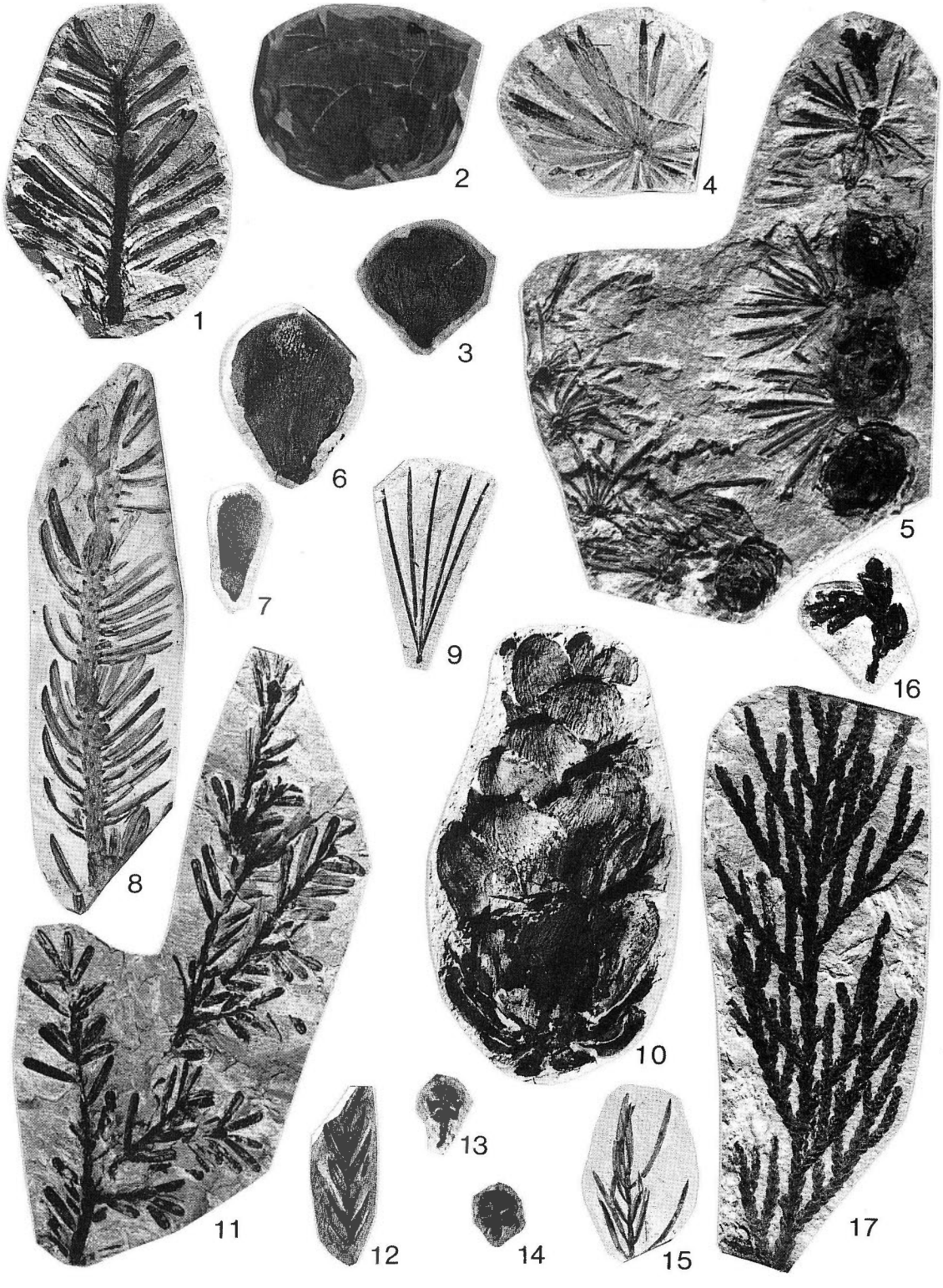
Fig. 11. *Tsuga sieboldii* CARRIERE (ツガ). SFPG no. 51.

Fig. 12. *Cryptomeria japonica* D. DON (スギ). YNU 31399.

Figs. 13, 14. *Chamaecyparis pisifera* (SIEBOLD et ZUCCARINI) SIEBOLD et ZUCCARINI (サワラ). SFPG nos. 145 (fig. 13), 194 (fig. 14).

Fig. 15. *Juniperus rigida* SIEBOLD et ZUCCARINI (ネズ). SFPG no. 195.

Figs. 16, 17. *Thuja standishii* (GORDON) CARRIERE (クロベ). SFPG no. 38 (fig. 16), GSJ F8016 (fig. 17).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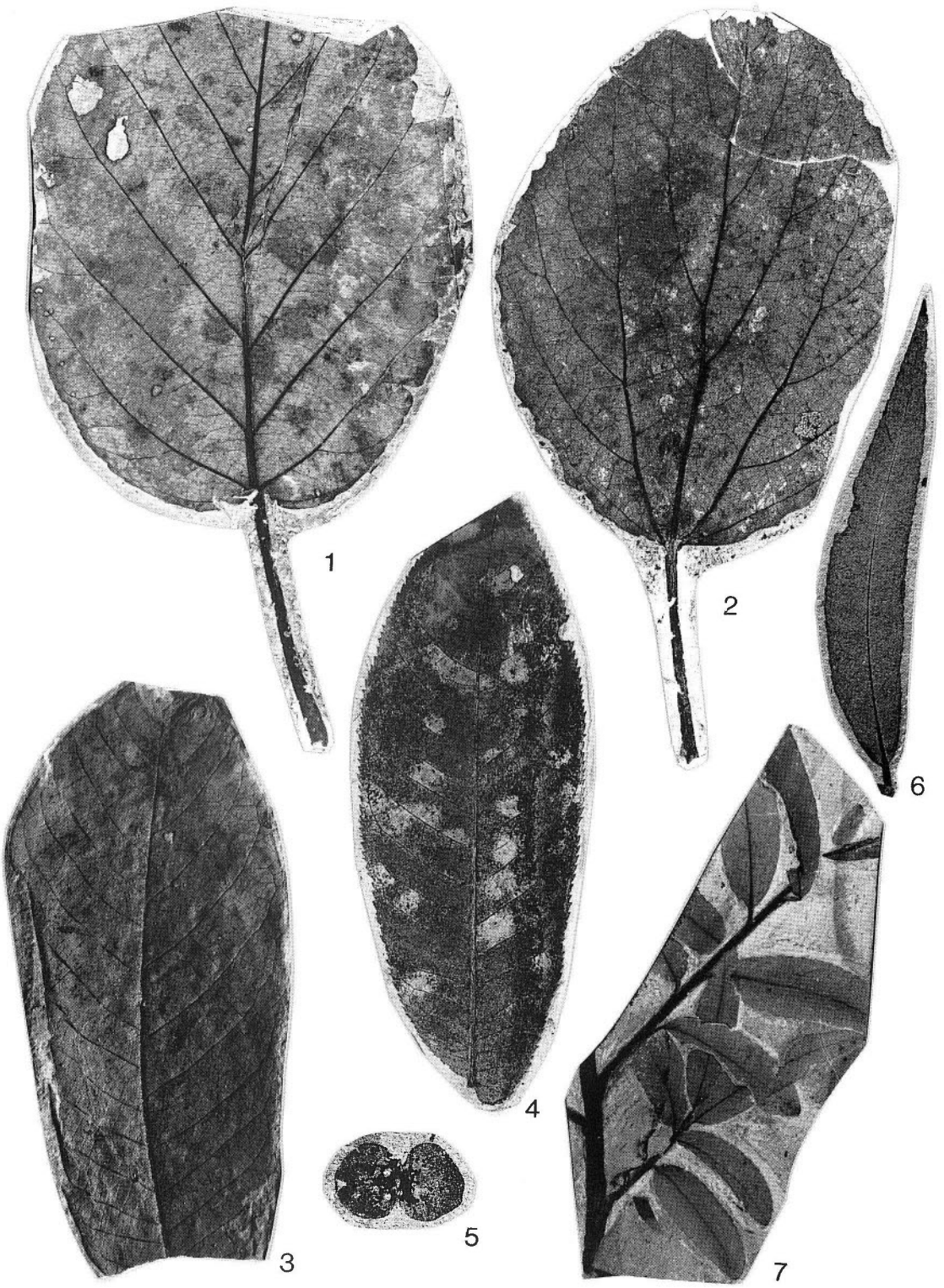
Explanation of Plate 3
(All figures in natural size)

Fig. 1. *Populus maximowiczii* HENRY (ドロノキ). SFPG no. 121.
Fig. 2. *Populus sieboldii* MIQUEL (ヤマナラシ). SFPG no. 52.
Fig. 3. *Juglans ailanthifolia* CARRIERE (オニグルミ). YNU 31400.
Figs. 4, 5. *Pterocarya rhoifolia* SIEBOLD et ZUCCARINI (サワグルミ). GSJ F7547 (fig. 4), SFPG no. 170 (fig. 5).
Fig. 6. *Salix sachalinensis* FR. SCHMIDT (オノエヤナギ). SFPG no. 40.
Fig. 7. *Salix integra* THUNBERG (イヌコリヤナギ). SFPG no. 155.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Explanation of Plate 4

(All figures in natural size unless otherwise stated)

Fig. 1. *Alnus maximowiczii* CALLIER (ミヤマハンノキ). SFPG no. 53.

Fig. 2. *Alnus hirsuta* var. *sibirica* (FISCHER) C. K. SCHNEIDER (ヤマハンノキ). GSJ F7549.

Fig. 3. *Alnus pendula* MATSUMURA (ヒメヤシャブシ). GSJ F8046.

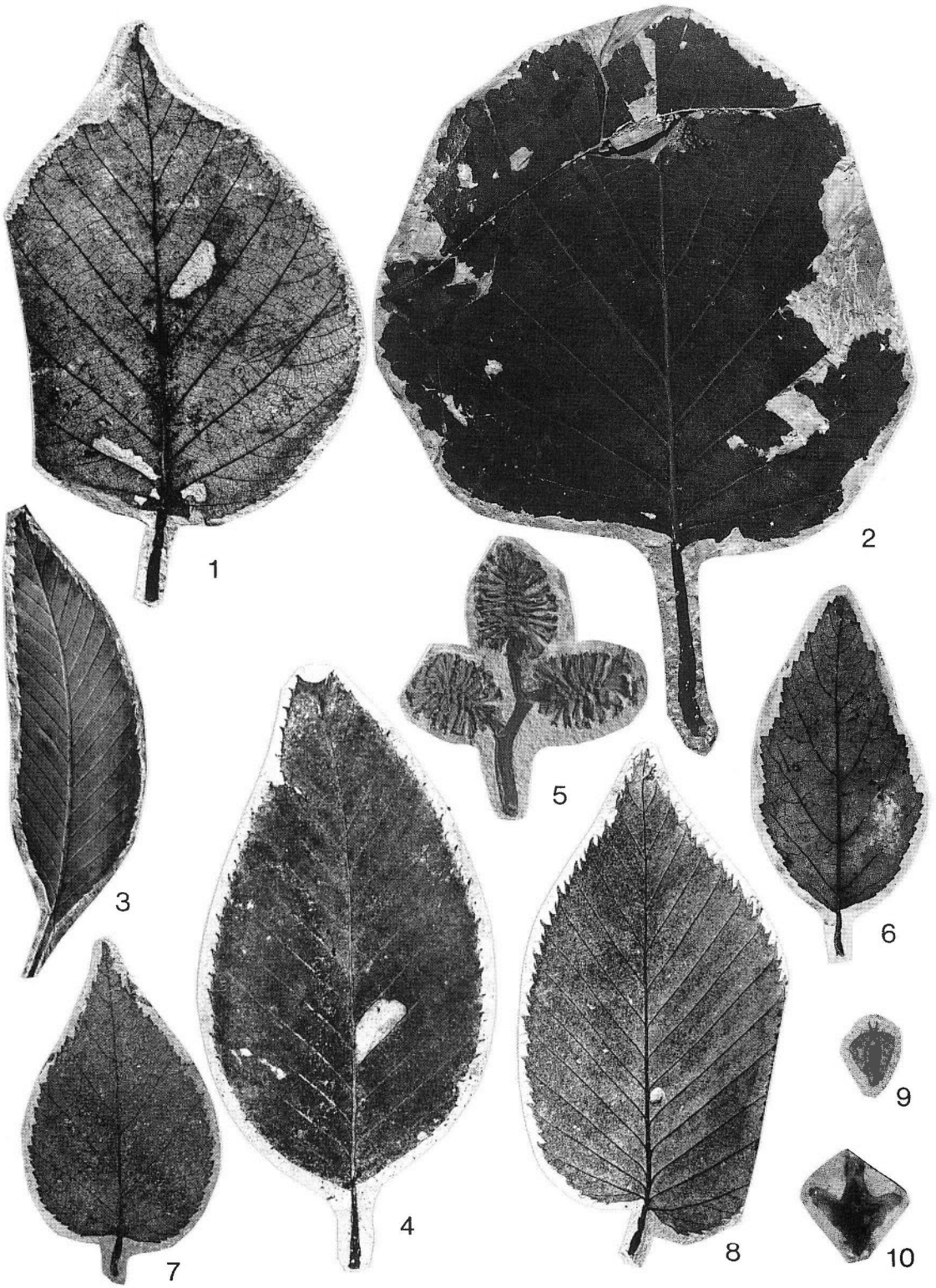
Fig. 4. *Alnus firma* SIEBOLD et ZUCCARINI (ヤシャブシ). GSJ F8047.

Fig. 5. *Alnus* sp. (ハンノキ属の1種). SFPG no. 171.

Fig. 6. *Betula davurica* PALLAS (ヤエガワカンバ). GSJ F8045.

Fig. 7. *Betula ermani* CHAMISSO (ダケカンバ). SFPG no. 139.

Figs. 8-10. *Betula grossa* SIEBOLD et ZUCCARINI (ミズメ). GSJ F8018 (fig. 8), 8017 (fig. 9, ×2), 8064 (fig. 10, ×2).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Explanation of Plate 5

(All figures in natural size unless otherwise stated)

Figs. 1-3. *Betula maximowicziana* REGEL (ウダイカンバ). GSJ F8065 (fig. 1, ×2), 8066 (fig. 2, ×2), 7554 (fig. 3).

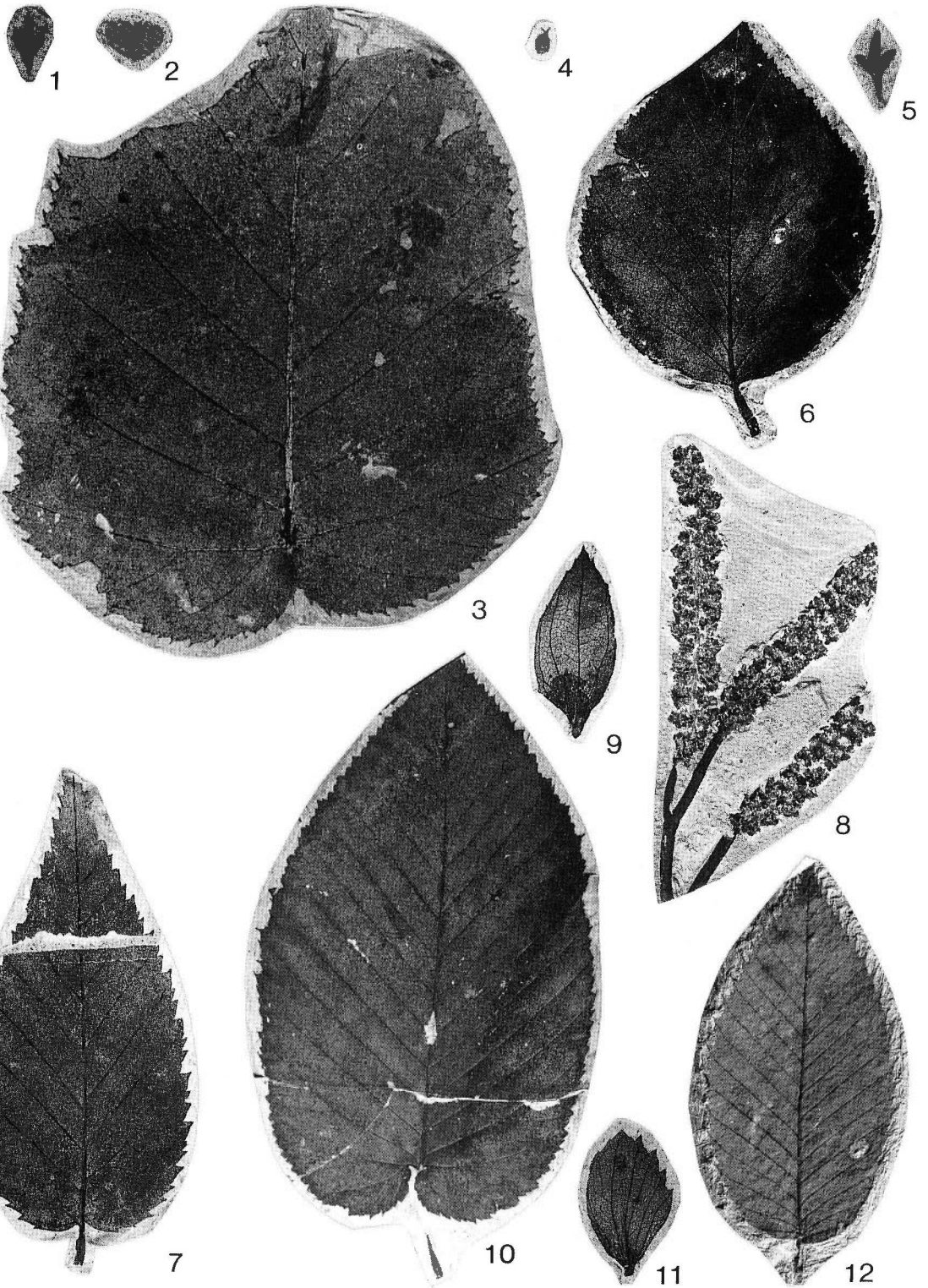
Figs. 4-6. *Betula schmidtii* REGEL (オノオレカンバ). GSJ F8067 (fig. 4, ×2), 8068 (fig. 5, ×2), 8019 (fig. 6).

Fig. 7. *Betula nikoensis* KOIDZUMI (マカンバ). SFPG no. 154.

Fig. 8. *Betula* sp. (カバノキ属の1種). SFPG no. 178.

Figs. 9, 10. *Carpinus cordata* BLUME (サワシバ). GSJ F8039 (fig. 9), 8020 (fig. 10).

Figs. 11, 12. *Carpinus japonica* BLUME (クマシデ). GSJ F8048 (fig. 11), 8021 (fig. 12).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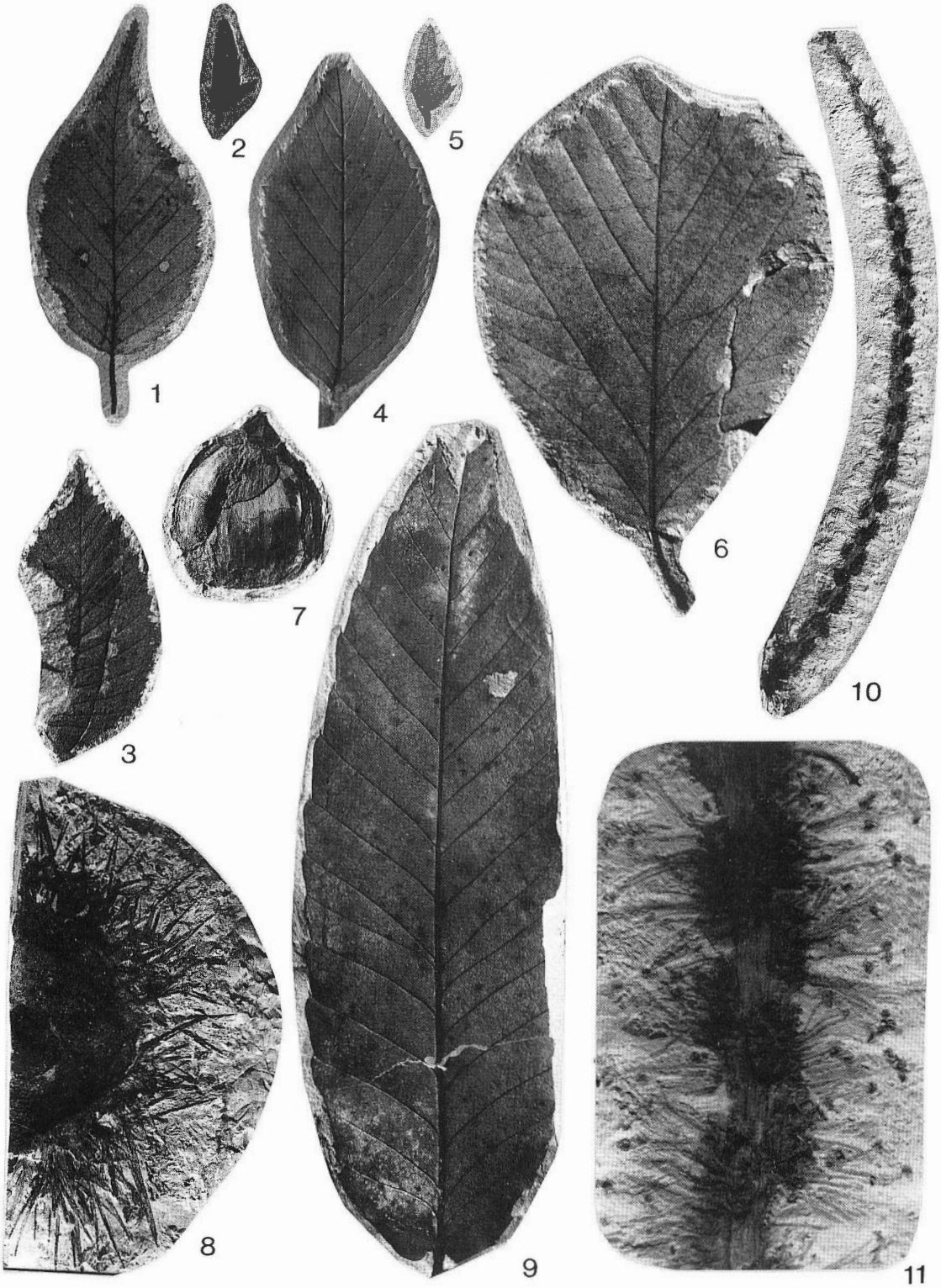
Explanation of Plate 6
(All figures in natural size unless otherwise stated)

Figs. 1-3. *Carpinus laxiflora* (SIEBOLD et ZUCCARINI) BLUME (アカシデ). GSJ F8024 (fig. 1), 8069 (fig. 2), KYOTO UNIV. (fig. 3).

Fig. 4, 5. *Carpinus tschonoskii* MAXIMOWICZ (イヌシデ). SFPG no. 144 (fig. 4), GSJ F8070 (fig. 5).

Fig. 6. *Corylus sieboldiana* BLUME (ツノハシバミ). SFPG no. 60.

Figs. 7-11. *Castanea crenata* SIEBOLD et ZUCCARINI (クリ). SFPG no. 31 (fig. 7), GSJ F8023 (fig. 8), 7538 (fig. 9), 8022 (fig. 10), enlarged of fig. 10, ×5 (fig. 11).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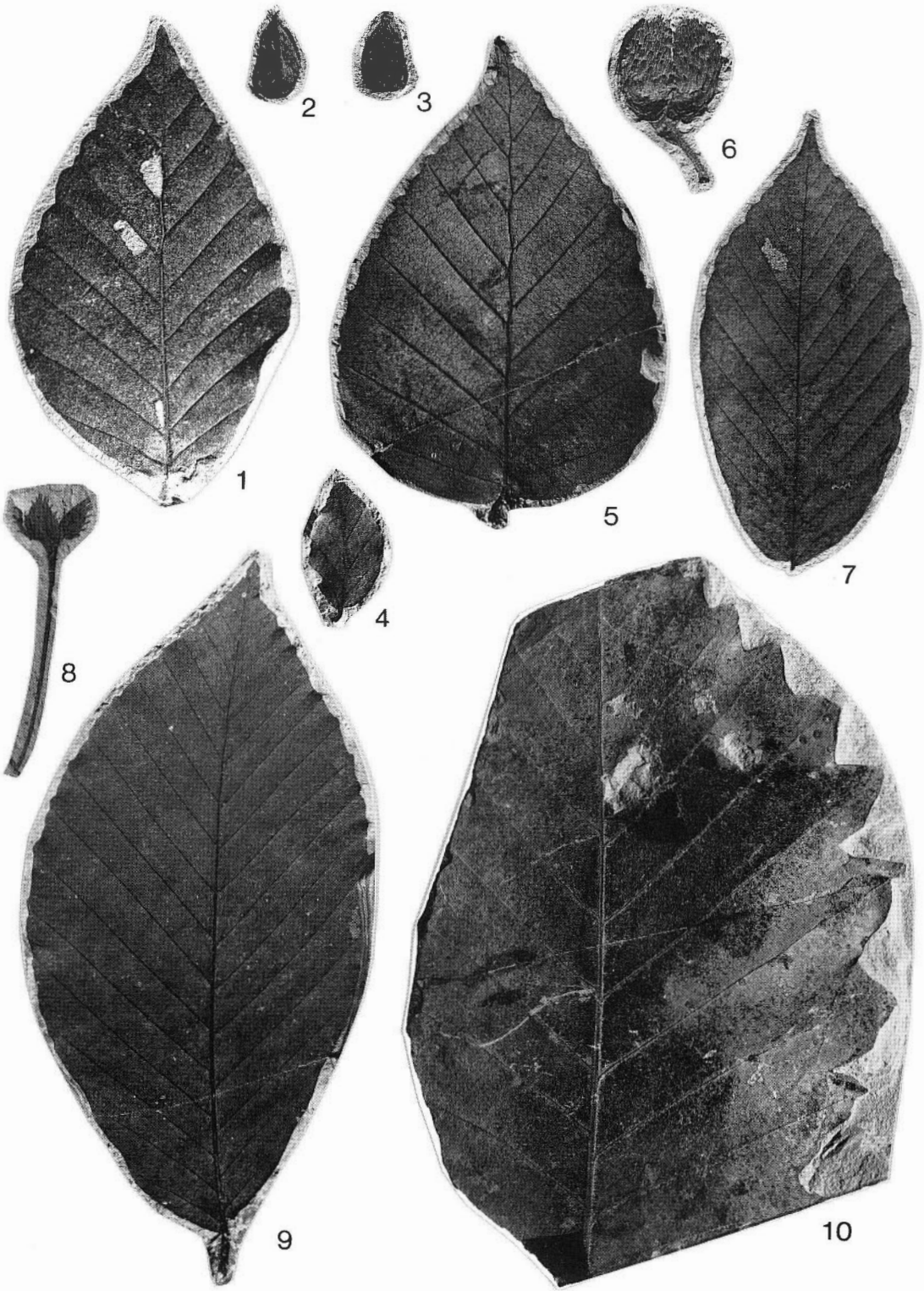
Explanation of Plate 7
(All figures in natural size)

Figs. 1-6. *Fagus crenata* BLUME (ブナ). GSJ F7526 (fig. 1), 8071-A (fig. 2), 8071-B (fig. 3), 8037 (fig. 4), 8025 (fig. 5), 8072 (fig. 6).

Figs. 7-9. *Fagus japonica* MAXIMOWICZ (イヌブナ). GSJ F8073 (fig. 7), 8074 (fig. 8), 8026 (fig. 9).

Fig. 10. *Quercus aliena* BLUME (ナラガシワ). SFPG no. 13.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Explanation of Plate 8

(All figures in natural size unless otherwise stated)

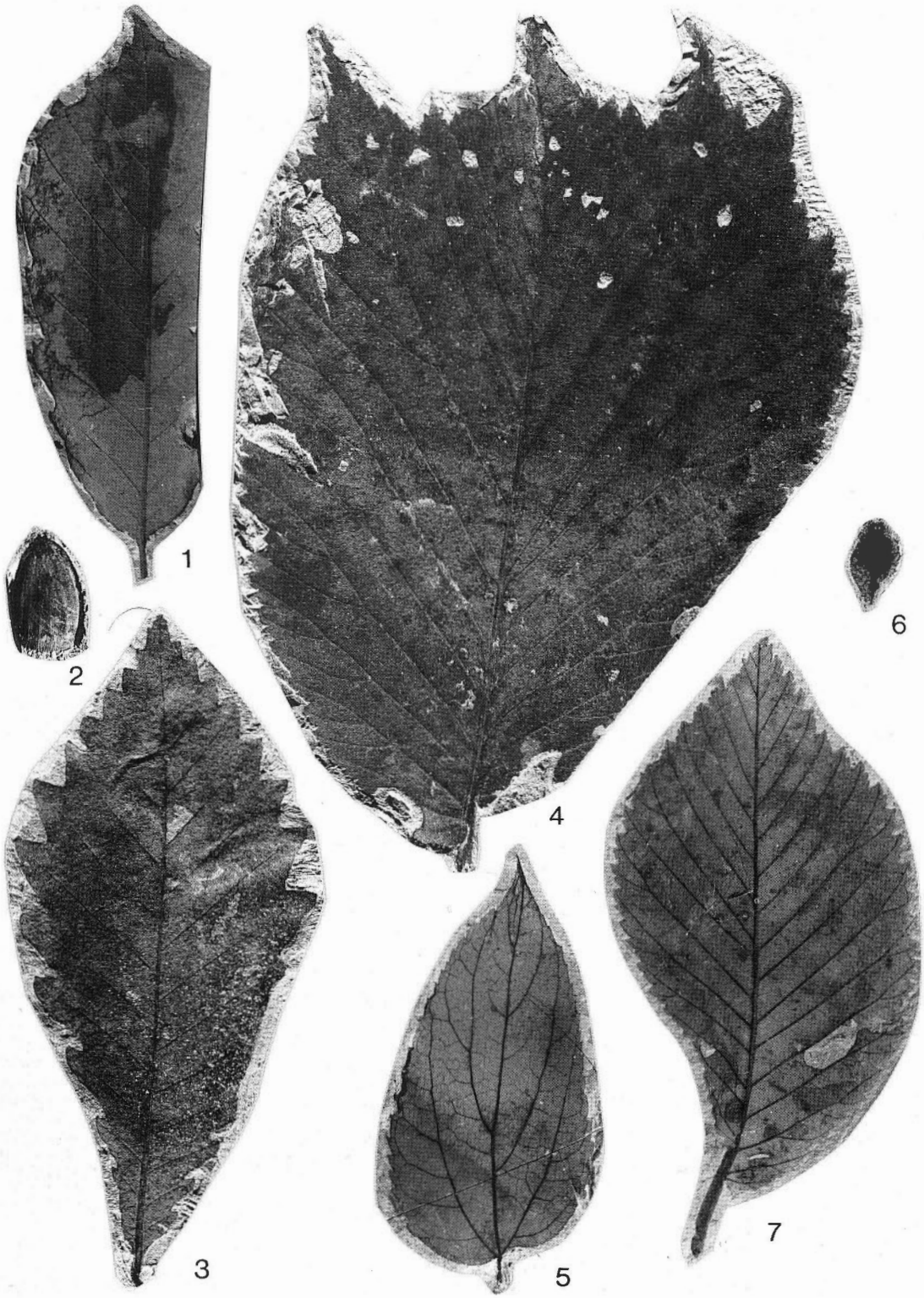
Fig. 1. *Quercus serrata* THUNBERG (コナラ). SFPG no. 61.

Figs. 2, 3. *Quercus mongolica* var. *grosseserrata* (BLUME) REHDER et WILSON (ミズナラ). SFPG no. 33 (fig. 2), GSJ F7545 (fig. 3).

Fig. 4. *Ulmus laciniata* (TRAUTVETTER) MAYR (オヒョウ). SFPG no. 19.

Fig. 5. *Celtis jessoensis* KOIDZUMI (エゾエノキ). GSJ F8027.

Figs. 6, 7. *Ulmus davidiana* var. *japonica* (REHDER) NAKAI (ハルニレ). SFPG no. 34 (fig. 6, ×1.4), GSJ F8028 (fig. 7).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Explanation of Plate 9
(All figures in natural size)

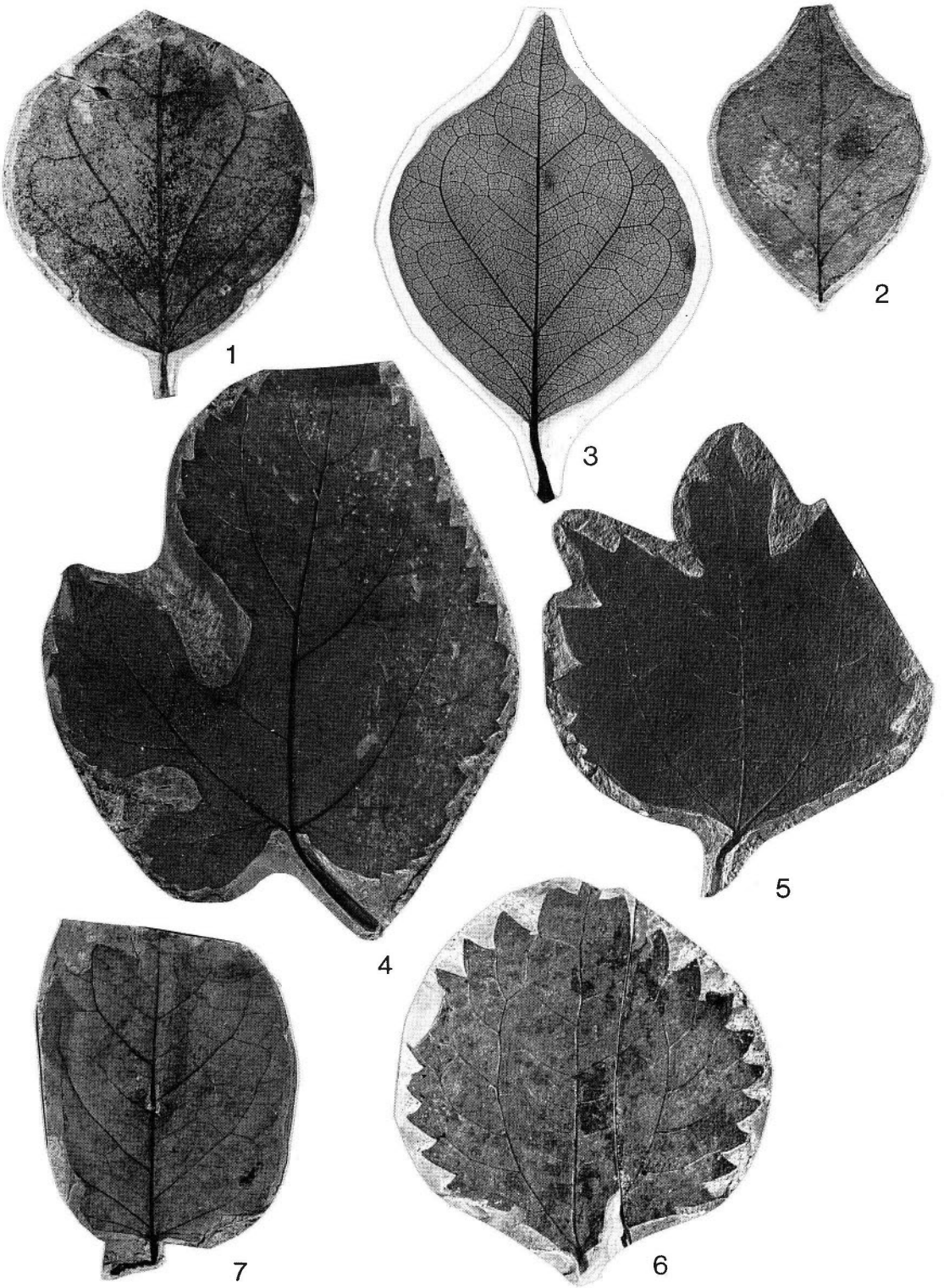
Figs. 1, 2. *Cudrania tricuspidata* (CARRIERE) BUREAU (ハリグワ). SFPG no. 146 (fig. 1), GSJ F8038 (fig. 2).

Fig. 3. *Cudrania tricuspidata* (CARRIERE) BUREAU (ハリグワ). Leaf of the living species for comparison.

Fig. 4. *Morus bombycis* KOIDZUMI (ヤマグワ). SFPG no. 62.

Figs. 5, 6. *Boehmeria tricuspis* (HANCE) MAKINO (アカソ). SFPG nos. 122 (fig. 5), 187 (fig. 6).

Fig. 7. *Polygonum cuspidatum* SIEBOLD et ZUCCARINI (イタドリ). SFPG no. 113.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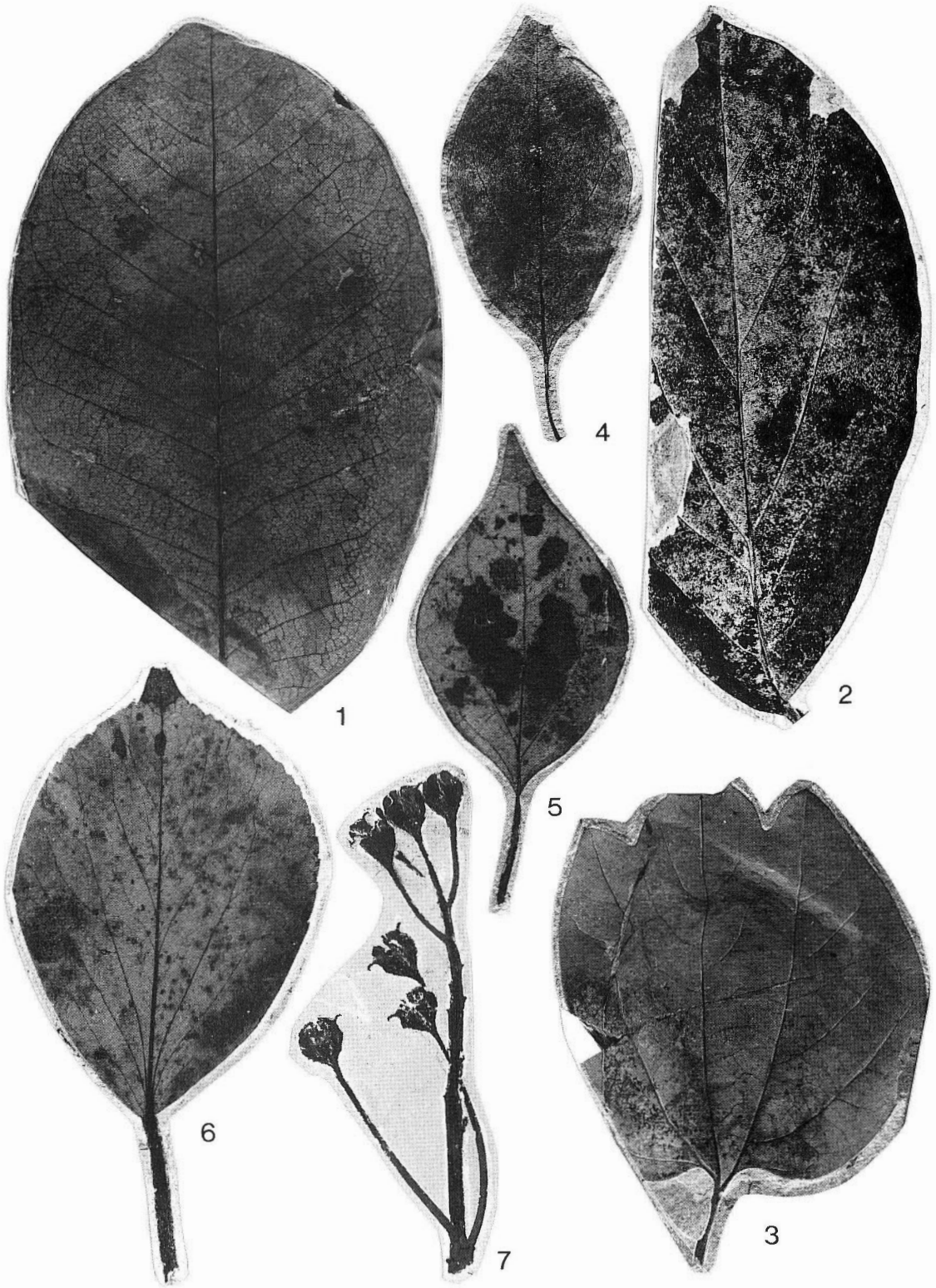
Explanation of Plate 10
(All figures in natural size)

Fig. 1. *Magnolia obovata* THUNBERG (ホオノキ). GSJ F7544.
Fig. 2. *Lindera membranacea* MAXIMOWICZ (オオバクロモジ). SFPG no. 116.
Fig. 3. *Lindera obtusiloba* BLUME (ダンコウバイ). GSJ F8029.
Fig. 4. *Lindera umbellata* THUNBERG (クロモジ). SFPG no. 66.
Fig. 5. *Parabenzoin praecox* (SIEBOLD et ZUCCARINI) NAKAI (アブラチャン). SFPG no. 49.
Figs. 6, 7. *Trochodendron aralioides* SIEBOLD et ZUCCARINI (ヤマグルマ). SFPG no. 63 (fig. 6), IGPS Reg. no. 40694 (fig. 7).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Explanation of Plate 11

(All figures in natural size unless otherwise stated)

Fig. 1. *Trochodendron aralioides* var. *longifolium* (MAXIMOWICZ) OHWI (ナガバノヤマグルマ). YNU 31391.

Figs. 2, 3. *Euptelea polyandra* SIEBOLD et ZUCCARINI (フサザクラ). GSJ F8075 (fig. 2), 8076 (fig. 3).

Figs. 4, 5. *Cercidiphyllum japonicum* SIEBOLD et ZUCCARINI (カツラ). GSJ F8030 (fig. 4), SFPG no. 189 (fig. 5, ×2).

Fig. 6. *Cercidiphyllum magnificum* (NAKAI) NAKAI (ヒロハカツラ). SFPG no. 125.

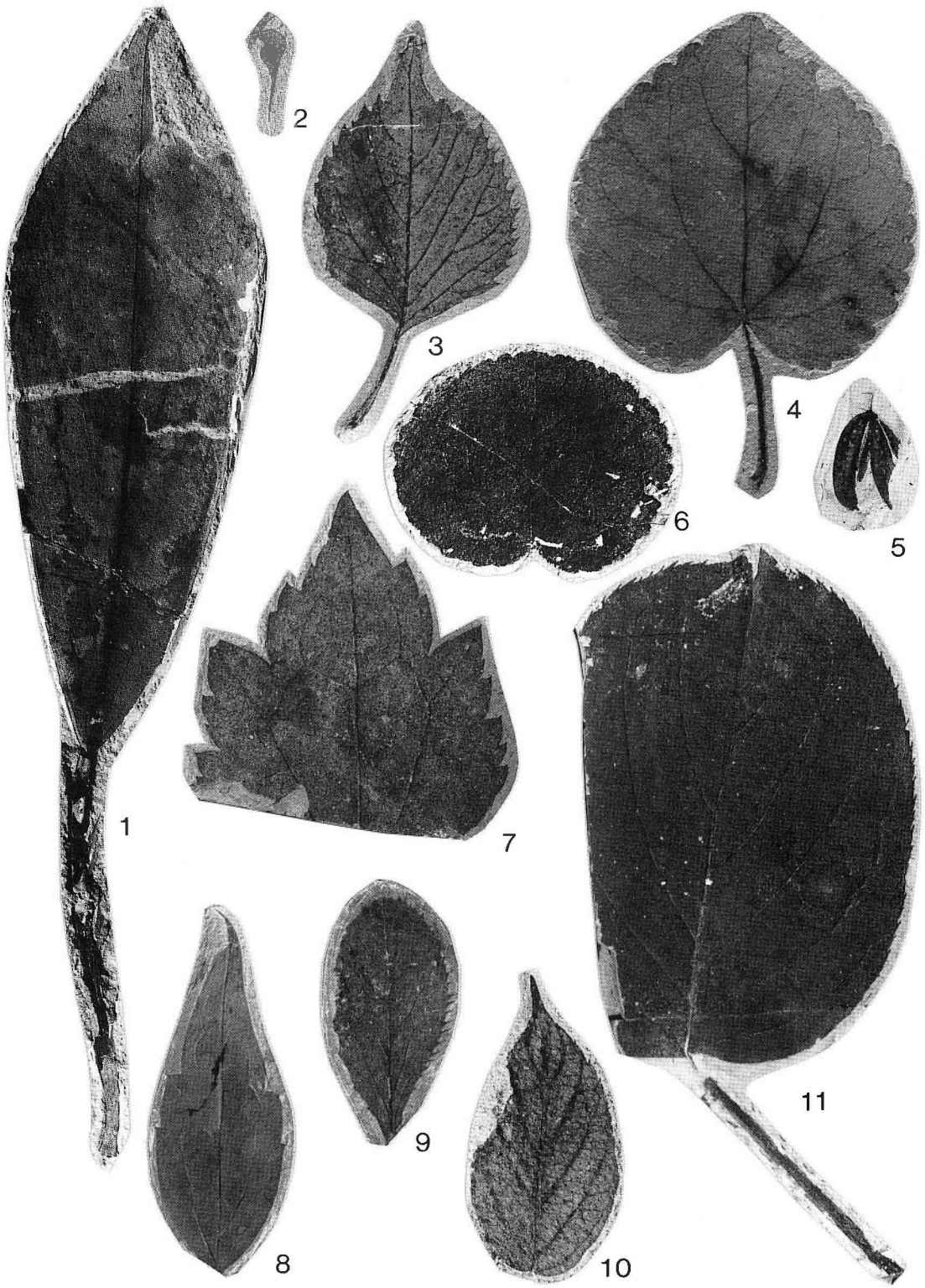
Fig. 7. *Clematis apiifolia* DE CANDOLLE (ボタンズル). SFPG no. 65.

Fig. 8. *Clematis apiifolia* var. *biternata* MAKINO (コボタンズル). SFPG no. 131.

Fig. 9. *Berberis amurensis* var. *japonica* (REGEL) REHDER (ヒロハヘビノボラズ). SFPG no. 134.

Fig. 10. *Actinidia polygama* (SIEBOLD et ZUCCARINI) MAXIMOWICZ (マタタビ). SFPG no. 120.

Fig. 11. *Actinidia arguta* (SIEBOLD et ZUCCARINI) PLANCHON ex MIQUEL (サルナシ). GSJ F8032.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Explanation of Plate 12

(All figures in natural size unless otherwise stated)

Fig. 1. *Stewartia pseudo-camellia* MAXIMOWICZ (ナツツバキ). GSJ F7540.

Fig. 2. *Deutzia scabra* THUNBERG (ウツギ). SFPG no. 126.

Fig. 3. *Ribes fasciculatum* SIEBOLD et ZUCCARINI (ヤブサンザシ). SFPG no. 138.

Figs. 4, 5. *Ceratophyllum demersum* LINNAEUS (マツモ). GSJ F8031 (fig. 5), enlarged the nut fossil from the specimen of fig. 5, ×2 (fig. 4).

Fig. 6. *Ribes ambiguum* MAXIMOWICZ (ヤシャビシャク). SFPG no. 70.

Fig. 7. *Schizophragma hydrangeoides* SIEBOLD et ZUCCARINI (イワガラミ). SFPG no. 71.

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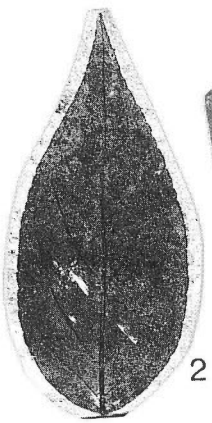

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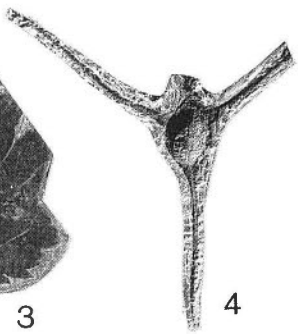

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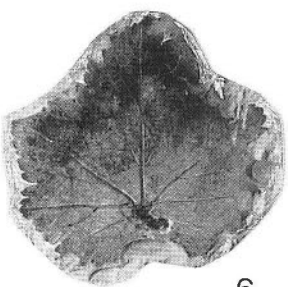

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Explanation of Plate 13
(All figures in natural size)

Fig. 1. *Corylopsis gotoana* MAKINO (ミヤマトサミズキ). SFPG no. 46.

Figs. 2, 3. *Hamamelis japonica* SIEBOLD et ZUCCARINI (マンサク). SFPG no. 185 (fig. 2), GSJ F8034 (fig. 3).

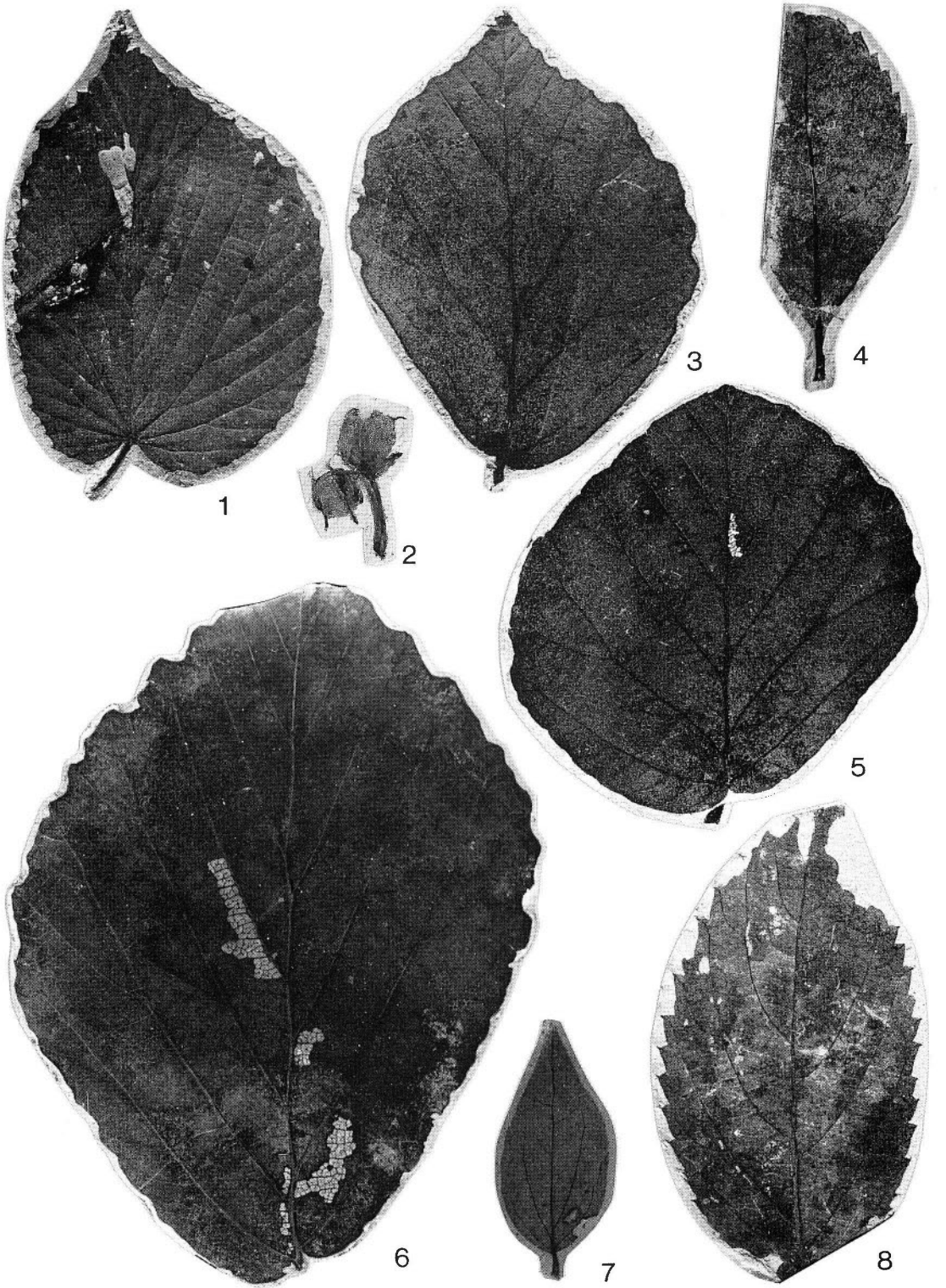
Fig. 4. *Hydrangea hirta* (THUNBERG) SIEBOLD (コアジサイ). IGPS Reg. no. 60930.

Fig. 5. *Hamamelis japonica* var. *obtusata* MATSUMURA (マルバマンサク). SFPG no. 72.

Fig. 6. *Hamamelis megalophylla* KOIDZUMI (オオバマンサク). SFPG no. 73.

Fig. 7. *Philadelphus satsumanus* SIEBOLD (バイカウツギ). SFPG no. 149.

Fig. 8. *Cardiandra alternifolia* SIEBOLD et ZUCCARINI (クサアジサイ). SFPG no. 128.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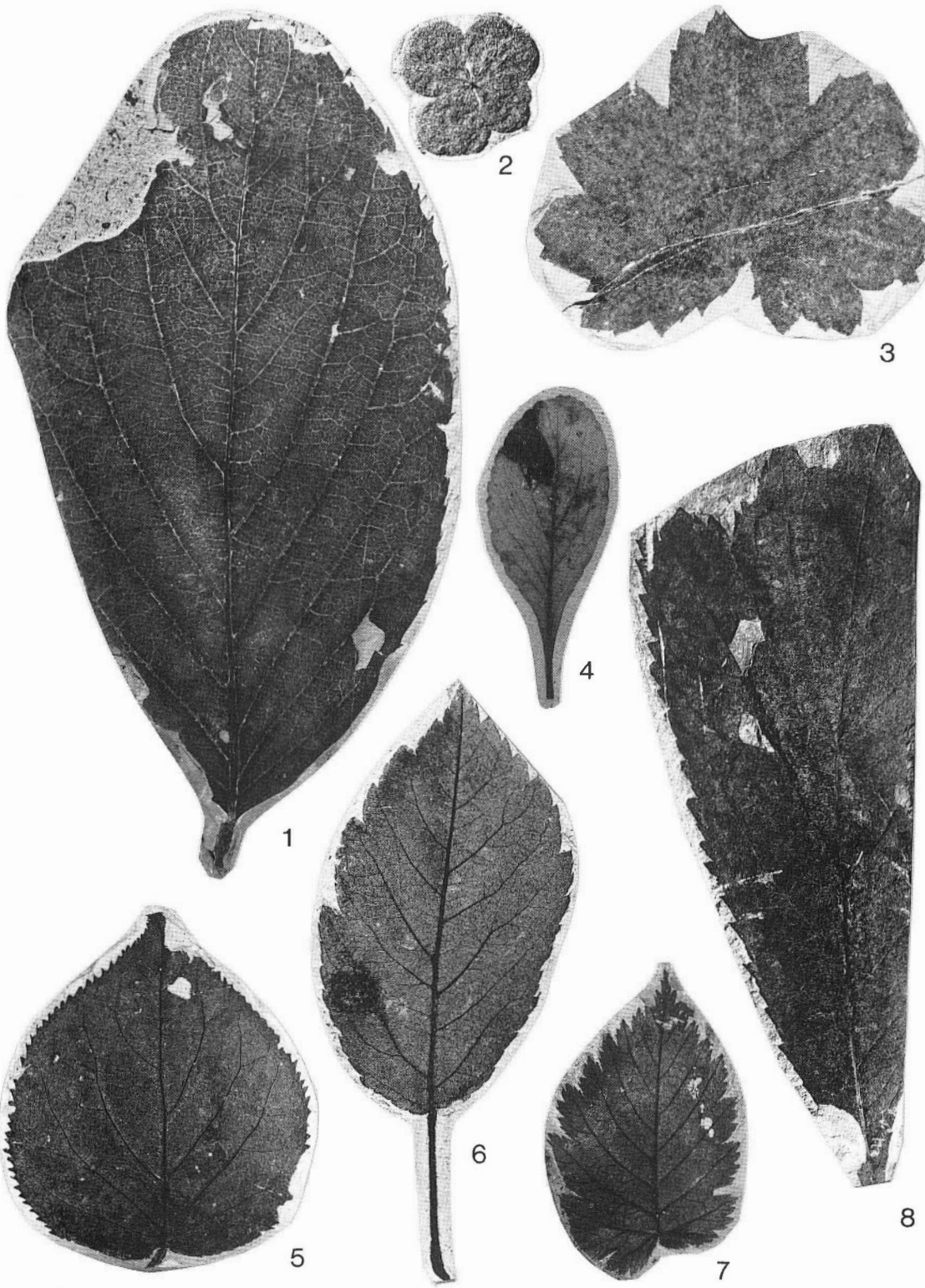
Explanation of Plate 14
(All figures in natural size)

Figs. 1, 2. *Hydrangea paniculata* SIEBOLD (ノリウツギ). GSJ F8033 (fig. 1), SFPG no. 27 (fig. 2).
Fig. 3. *Saxifraga fortunei* HOOKER (ダイモンジソウ). SFPG no. 127.
Fig. 4. *Chaenomeles japonica* (THUNBERG) LINDLEY (クサボケ). SFPG no. 132.
Fig. 5. *Hydrangea petiolaris* SIEBOLD et ZUCCARINI (ツルアジサイ). SFPG no. 124.
Fig. 6. *Malus sieboldii* (REGEL) REHDER (ズミ). SFPG no. 76.
Fig. 7. *Aruncus sylvester* KOSTELETZKY (ヤマブキショウマ). SFPG no. 129.
Fig. 8. *Rodgersia podophylla* A. GRAY (ヤグルマソウ). SFPG no. 162.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Explanation of Plate 15
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Fig. 1. *Prunus apetala* (SIEBOLD et ZUCCARINI) FRANCHET et SAVATIER (チョウジザクラ). SFPG no. 25.

Fig. 2. *Kerria japonica* (THUNBERG) DE CANDOLLE (ヤマブキ). SFPG no. 75.

Figs. 3, 4. *Potentilla fragarioides* var. *major* MAXIMOWICZ (キジムシロ). SFPG nos. 142 (fig. 3), 74 (fig. 4).

Fig. 5. *Crataegus maximowiczii* C. K. SCHNEIDER (オオバサンザシ). SFPG no. 133.

Fig. 6. *Pourthiaea villosa* (THUNBERG) DECAISNE (カマツカ). SFPG no. 93.

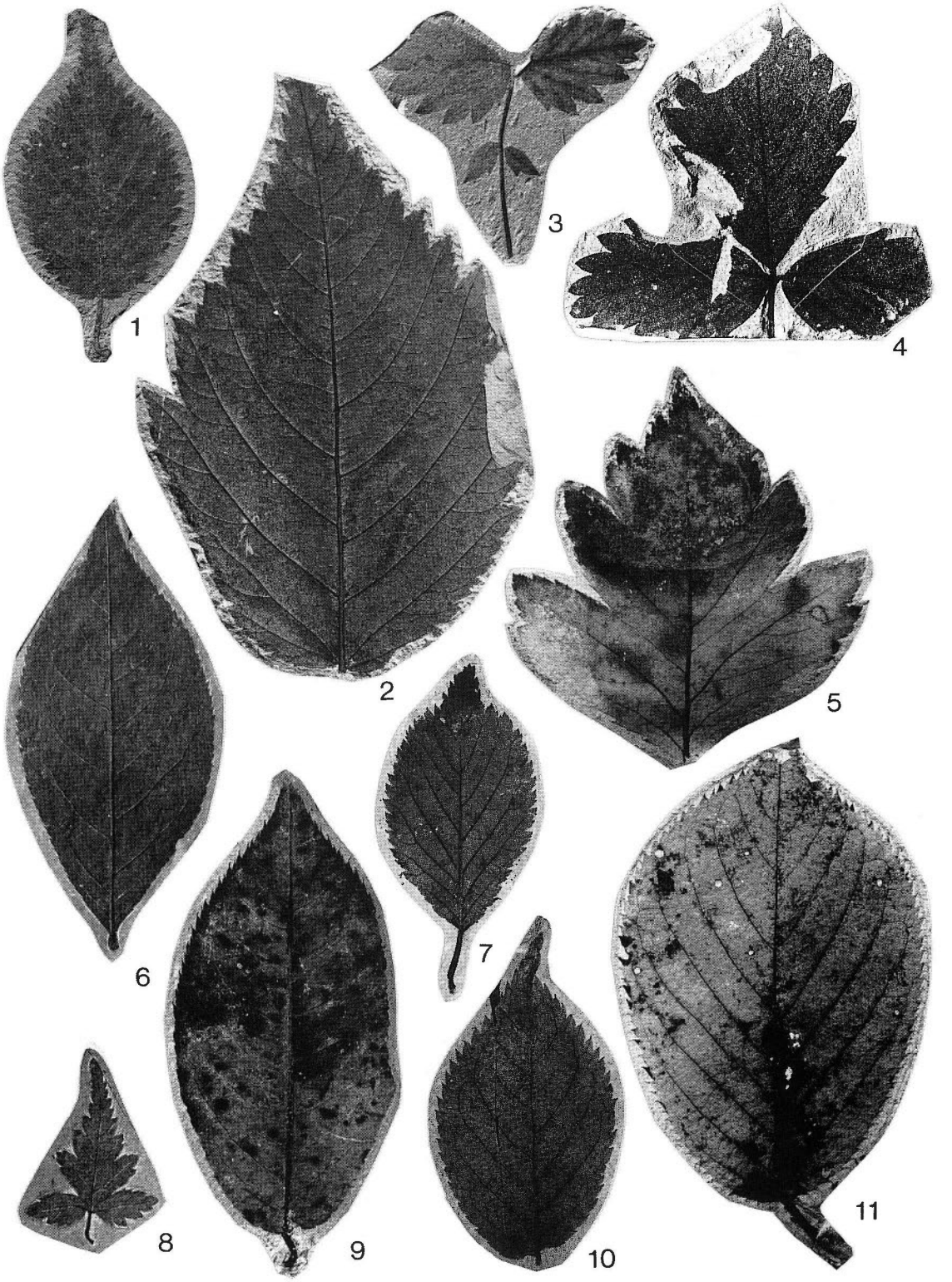
Fig. 7. *Prunus nipponica* MATSUMURA (ミネザクラ). SFPG no. 115.

Fig. 8. *Stephanandra incisa* (THUNBERG) ZABEL (コゴメウツギ). SFPG no. 84.

Fig. 9. *Prunus ssiori* FR. SCHMIDT (シウリザクラ). SFPG no. 79.

Fig. 10. *Prunus maximowiczii* RUPRECHT (ミヤマザクラ). SFPG no. 186.

Fig. 11. *Prunus jamasakura* SIEBOLD ex KOIDZUMI (ヤマザクラ). SFPG no. 77.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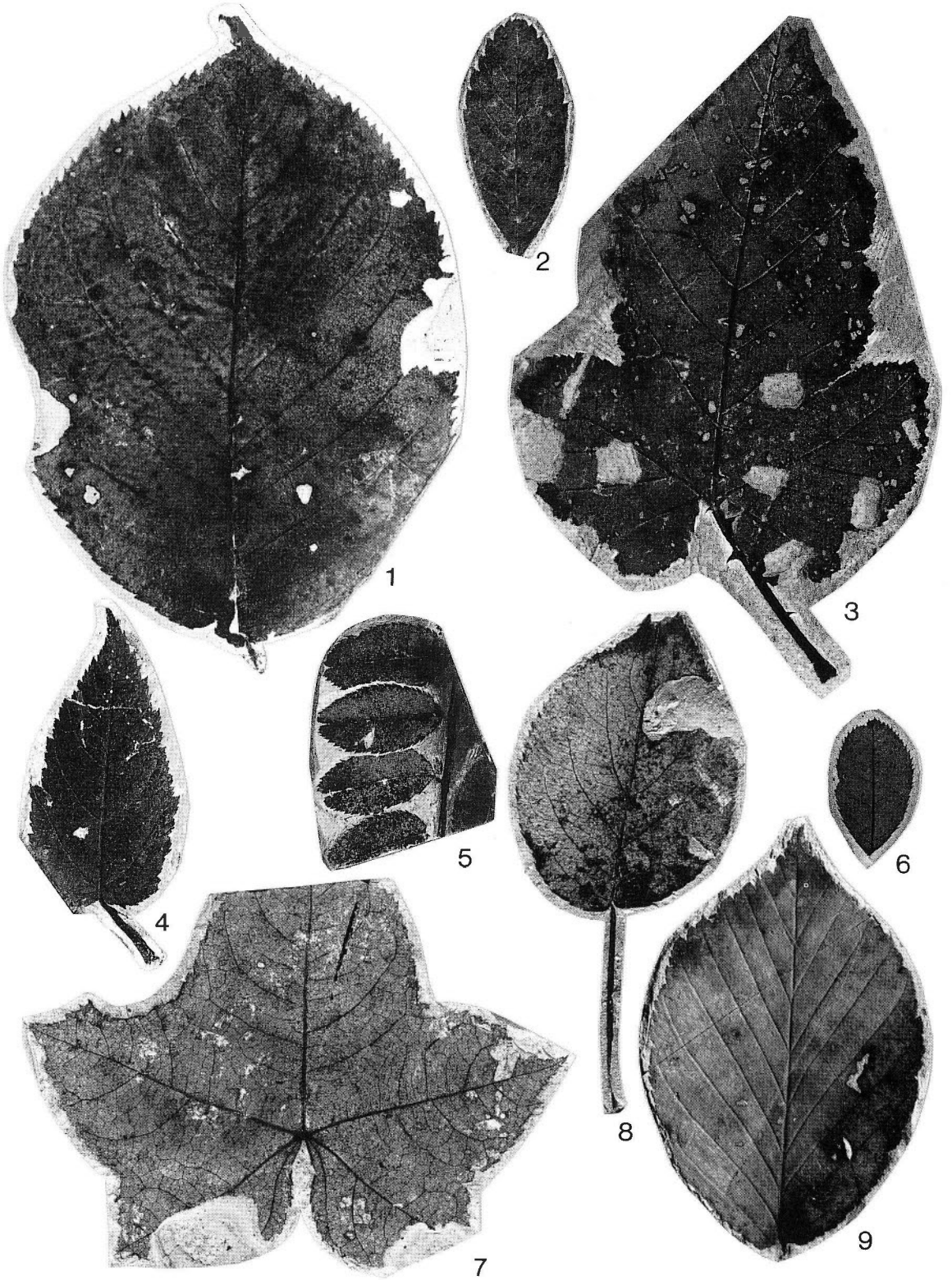
Explanation of Plate 16
(All figures in natural size)

Fig. 1. *Prunus sargentii* REHDER (オオヤマザクラ). SFPG no. 78.
Fig. 2. *Sorbus gracilis* (SIEBOLD et ZUCCARINI) C. KOCH (ナンキンナナカマド). SFPG no. 83.
Fig. 3. *Rubus crataegifolius* BUNGE (クマイチゴ). SFPG no. 130.
Fig. 4. *Rubus palmatus* THUNBERG (ナガバモミジイチゴ). SFPG no. 82.
Figs. 5, 6. *Rosa multiflora* THUNBERG (ノイバラ). SFPG nos. 81 (fig. 5), 197 (fig. 6).
Fig. 7. *Rubus* sp. (キイチゴ属の1種). SFPG no. 137.
Fig. 8. *Pyrus pyrifolia* (BURMAN) NAKAI (ヤマナシ). SFPG no. 80.
Fig. 9. *Sorbus alnifolia* (SIEBOLD et ZUCCARINI) C. KOCH (アズキナシ). GSJ F8035.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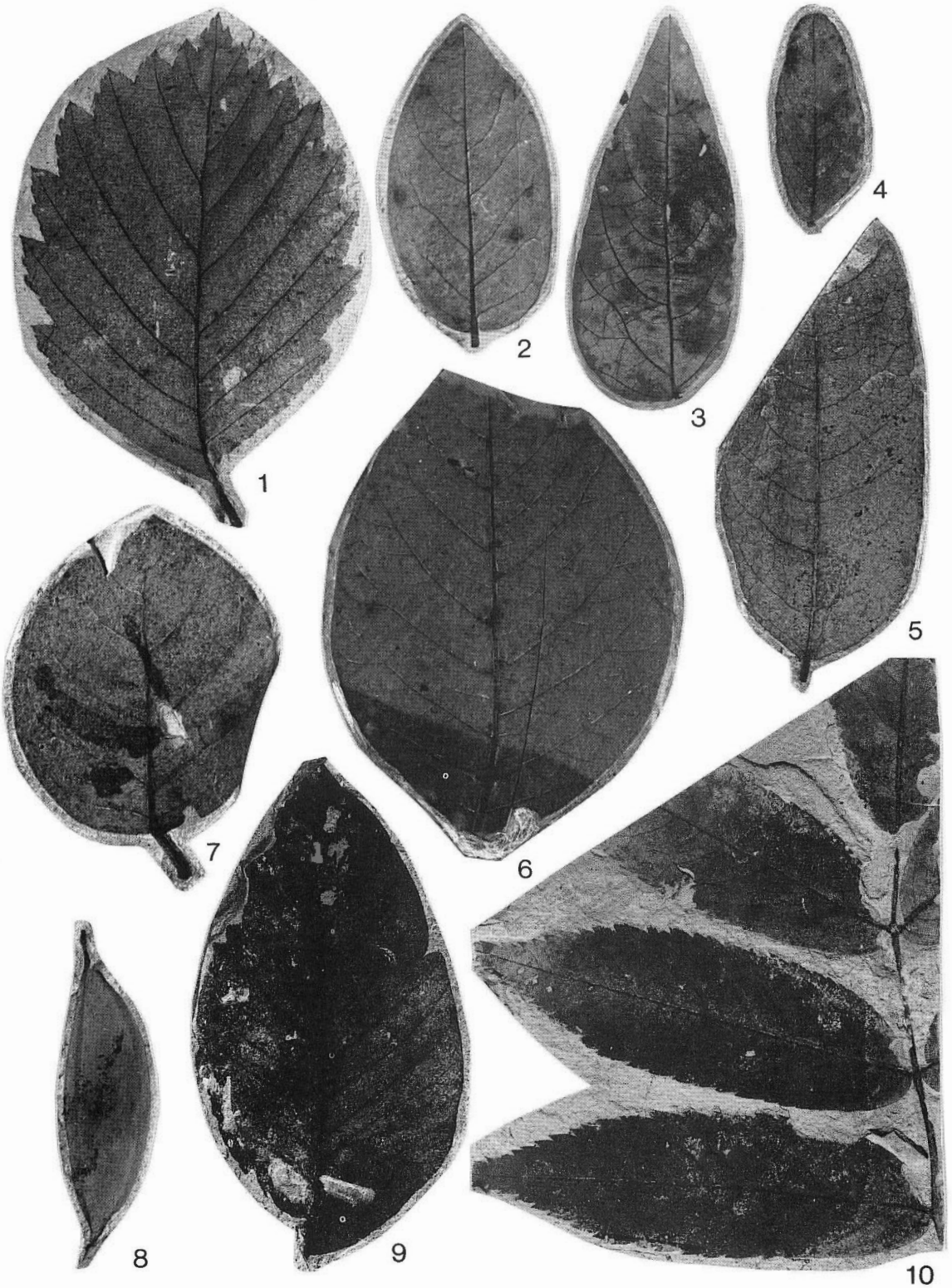
Explanation of Plate 17
(All figures in natural size)

Fig. 1. *Sorbus japonica* (DECAISNE) HEDLUND (ウラジロ). GSJ F7536.
Fig. 2. *Macckia amurensis* var. *buergeri* (MAXIMOWICZ) C. K. SCHNEIDER (イヌエンジュ). SFPG no. 141.
Fig. 3. *Dumasia truncata* SIEBOLD et ZUCCARINI (ノササゲ). SFPG no. 160.
Fig. 4. *Gleditsia japonica* MIQUEL (サイカチ). SFPG no. 86.
Fig. 5. *Wisteria floribunda* (WILLDENOW) DE CANDOLLE (フジ). SFPG no. 87.
Fig. 6. *Rhus ambigua* LAVALLEE ex DIPPEL (ツタウルシ). SFPG no. 90.
Fig. 7. *Sapium japonicum* (SIEBOLD et ZUCCARINI) PAX et HOFFMANN (シラキ). SFPG no. 88.
Fig. 8. *Cladrastis platycarpa* (MAXIMOWICZ) MAKINO (フジキ). GSJ F12713.
Fig. 9. *Rhus trichocarpa* MIQUEL (ヤマウルシ). SFPG no. 92.
Fig. 10. *Sorbus commixta* HENDLUND (ナナカマド). GSJ F8036.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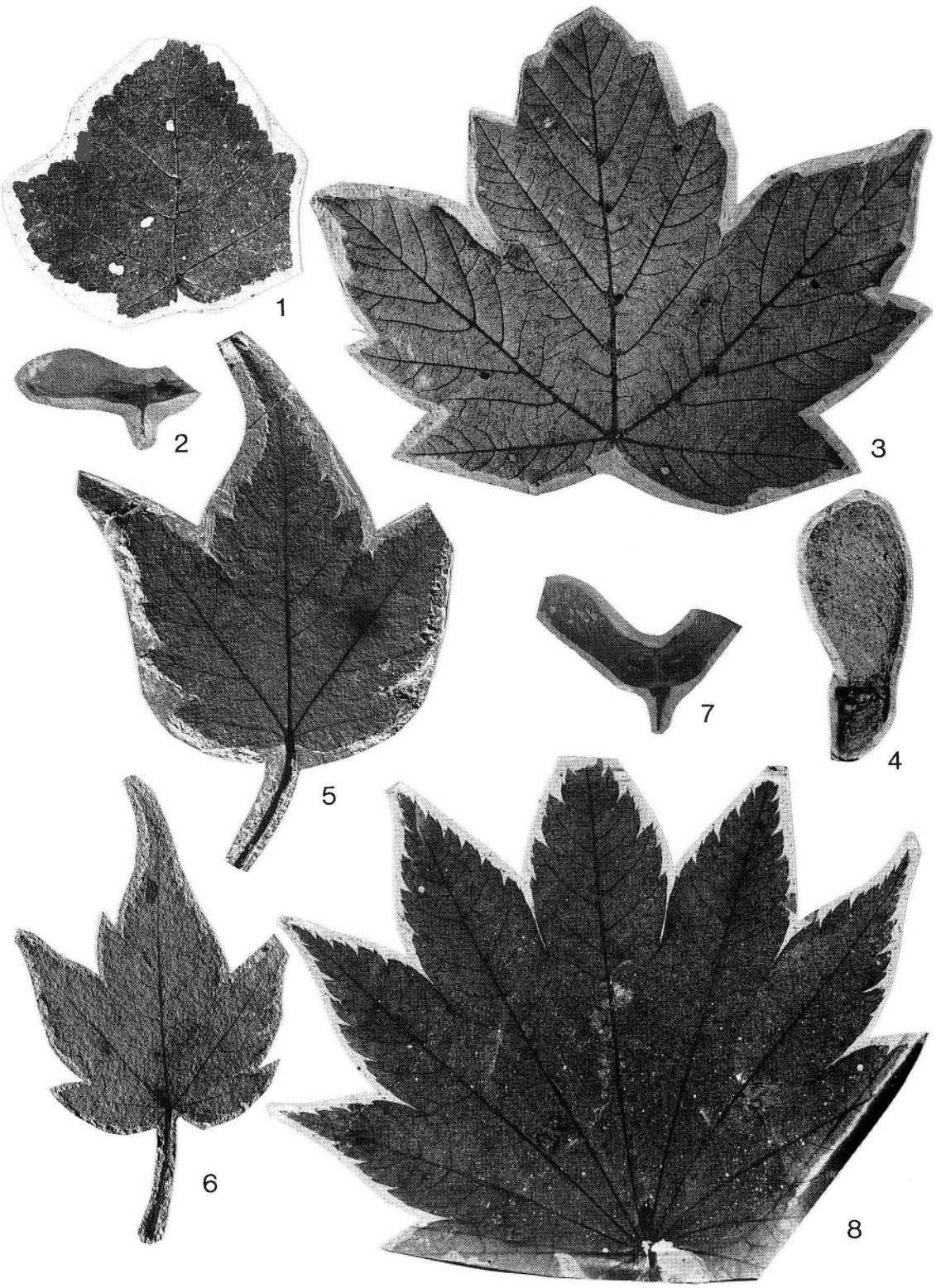
Explanation of Plate 18
(All figures in natural size)

Figs. 1, 2. *Acer crataegifolium* SIEBOLD et ZUCCARINI (ウリカエデ). SFPG nos. 190 (fig. 1), 191 (fig. 2).

Figs. 3, 4. *Acer diabolicum* BLUME ex KOCH (カジカエデ). SFPG no. 11 (fig. 3), GSJ F8077 (fig. 4).

Figs. 5, 6. *Acer micranthum* SIEBOLD et ZUCCARINI (コミネカエデ). GSJ F8040 (fig. 5), SFPG no. 4 (fig. 6).

Figs. 7, 8. *Acer japonicum* THUNBERG (ハウチワカエデ). SFPG no. 193 (fig. 7), GSJ F12714 (fig. 8).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Explanation of Plate 19
(All figures in natural size)

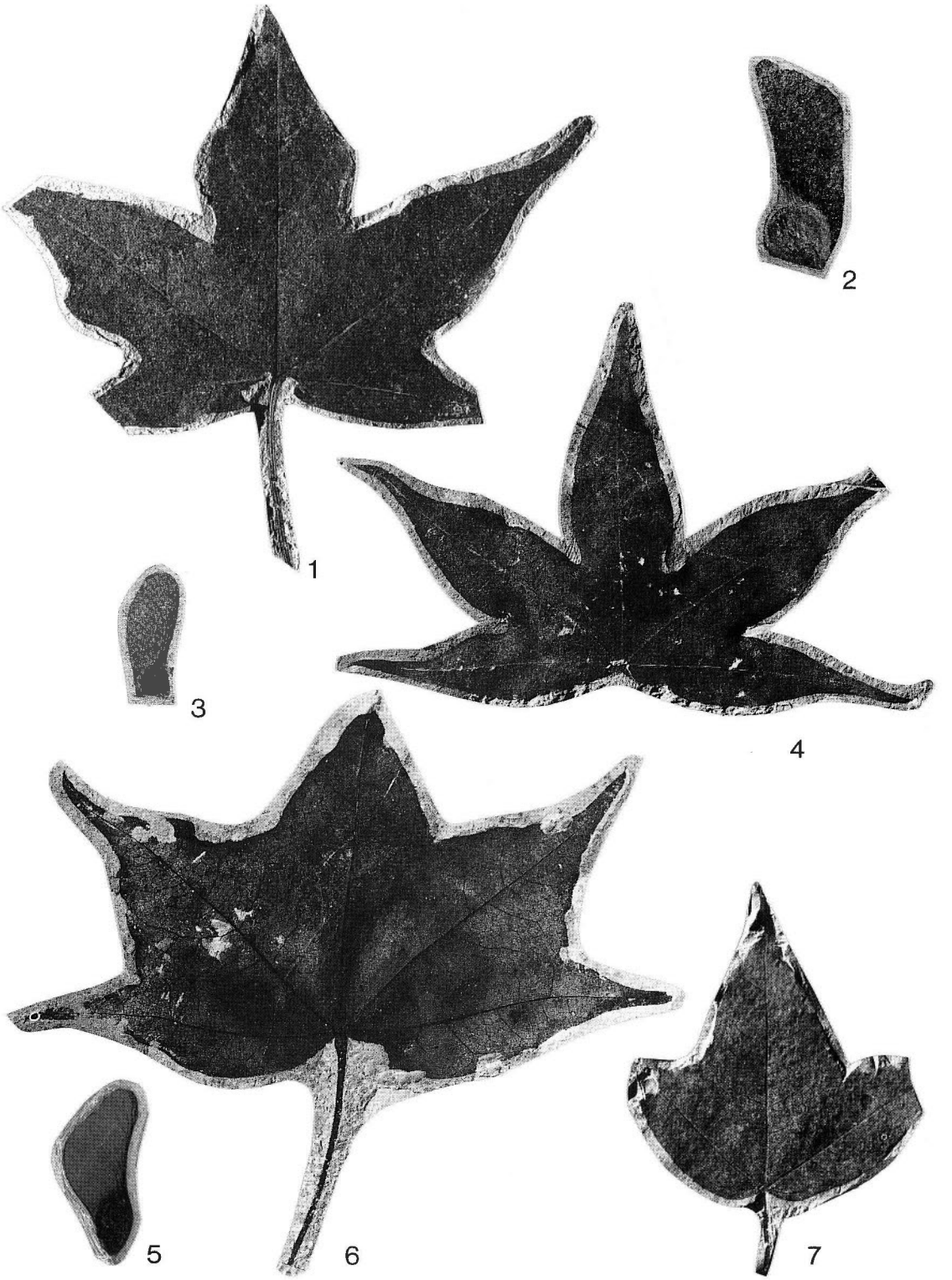
Figs. 1, 2. *Acer miyabei* MAXIMOWICZ (クロビイタヤ). GSJ F8041 (fig. 1), SFPG no. 1 (fig. 2).

Fig. 3. *Acer sieboldianum* MIQUEL (コハウチワカエデ). SFPG no. 8.

Fig. 4. *Acer mono* var. *marmoratum* (NICHOLS) HARA (エンコウカエデ). SFPG no. 12.

Figs. 5, 6. *Acer mono* MAXIMOWICZ (イタヤカエデ). SFPG no. 94 (fig. 5), GSJ F8042 (fig. 6).

Fig. 7. *Acer mono* var. *glaucum* (KOIDZUMI) SUGIYAMA (ウラジロイタヤ). SFPG no. 9.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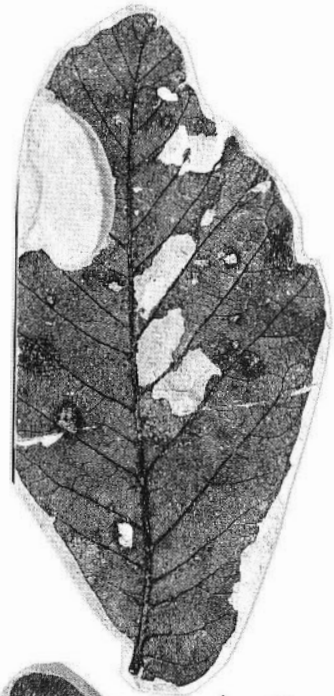
Explanation of Plate 20
(All figures in natural size)

Figs. 1-3. *Acer nikoense* MAXIMOWICZ (メグスリノキ). GSJ F8043 (fig. 1), SFPG no. 95 (fig. 2), GSJ F8044 (fig. 3).

Fig. 4. *Acer palmatum* var. *amoenum* (CARRIERE) OHWI (オオモミジ). SFPG no. 10.

Fig. 5. *Acer tenuifolium* (KOIDZUMI) KOIDZUMI (ヒナウチワカエデ). SFPG no. 7.

Figs. 6, 7. *Acer rufinerve* SIEBOLD et ZUCCARINI (ウリハダカエデ). SFPG nos. 2 (fig. 6), 196 (fig. 7).



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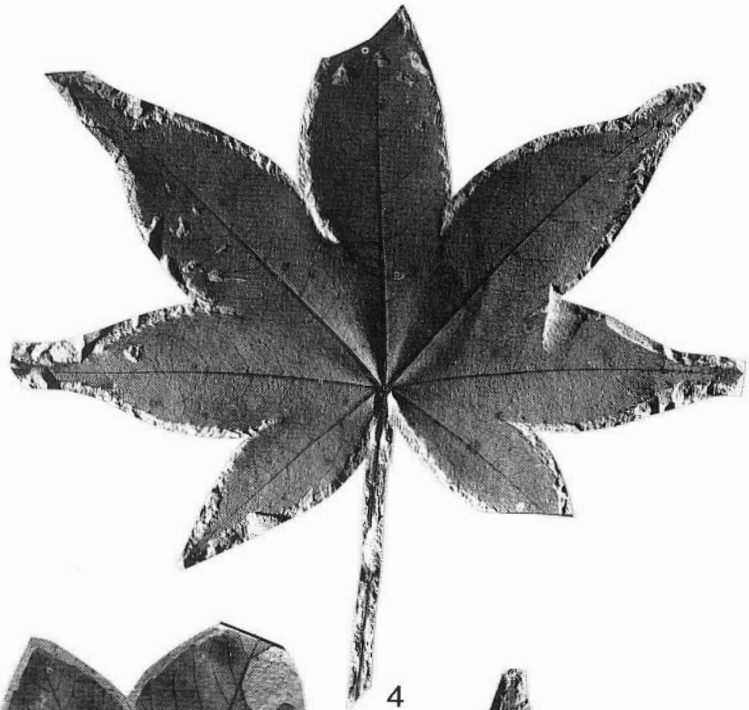

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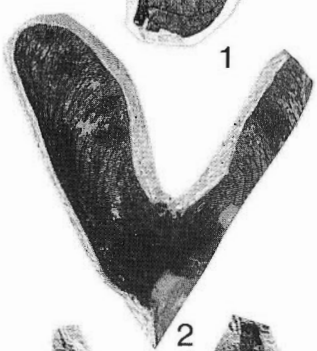

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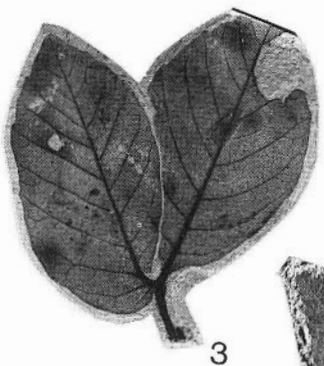

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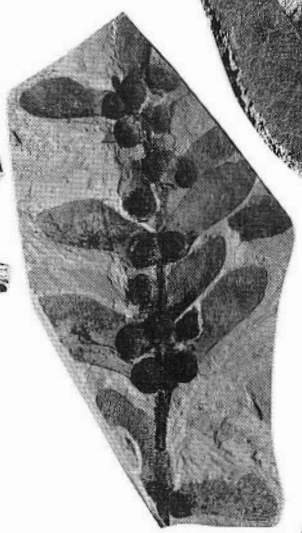

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Explanation of Plate 21
(All figures in natural size)

Fig. 1. *Aesculus turbinata* BLUME (トチノキ). SFPG no. 96.

Fig. 2. *Ilex macropoda* MIQUEL (アオハダ). SFPG no. 143.

Figs. 3, 4. *Buxus microphylla* var. *japonica* (MUELLER) REHDER et WILSON (ツゲ). GSJ F12715 (fig. 3), SFPG no. 198 (fig. 4).

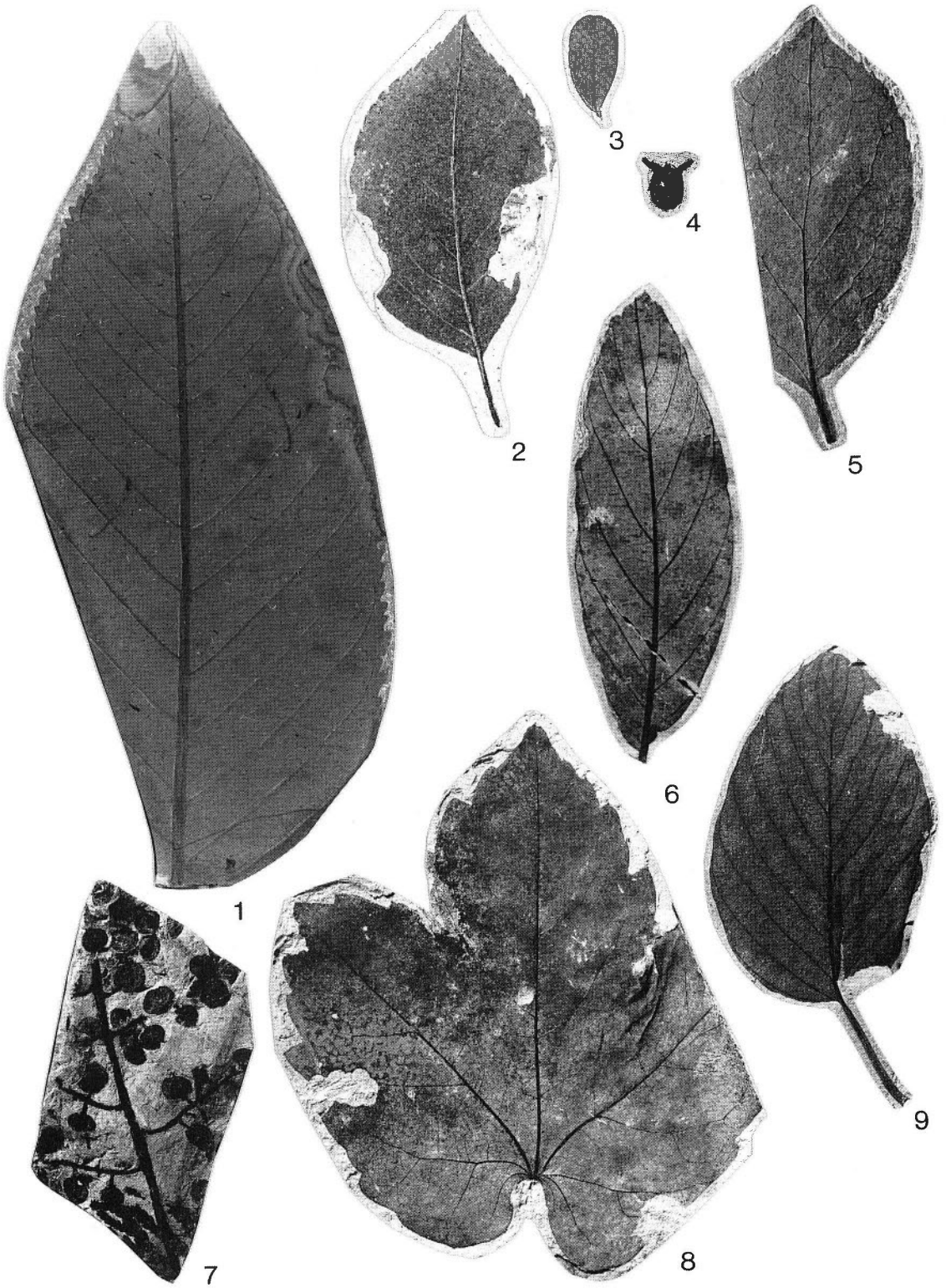
Fig. 5. *Celastrus orbiculatus* THUNBERG (ツルウメモドキ). SFPG no. 117.

Fig. 6. *Berchemia berchemiaefolia* (MAKINO) KOIDZUMI (ヨコグラノキ). GSJ F12716.

Fig. 7. *Rhus trichocarpa* MIQUEL (ヤマウルシ). SFPG no. 91.

Fig. 8. *Parthenocissus tricuspidata* (SIEBOLD et ZUCCARINI) PLANCHON (ツタ). GSJ F8049.

Fig. 9. *Berchemia racemosa* SIEBOLD et ZUCCARINI (クマヤナギ). GSJ F8061.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Explanation of Plate 22

(All figures in natural size unless otherwise stated)

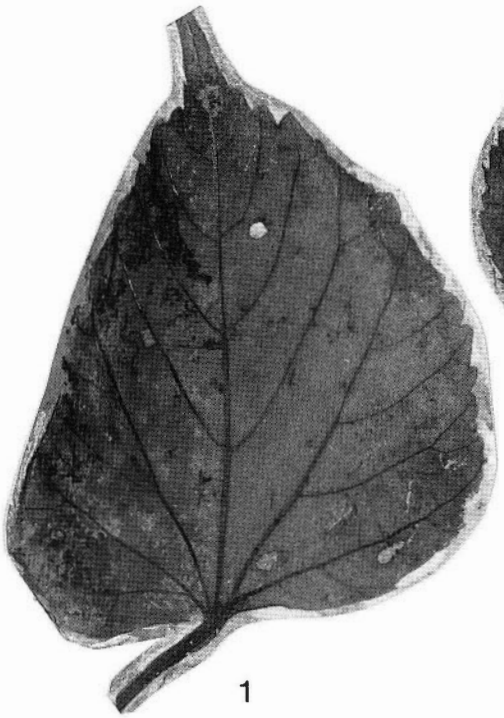
Fig. 1. *Vitis flexuosa* THUNBERG (サンカクヅル). SFPG no. 180.

Figs. 2, 3. *Tilia japonica* (MIQUEL) SIMONKAI (シナノキ). GSJ F12717 (fig. 2), SFPG no. 199 (fig. 3).

Fig. 4. *Parthenocissus tricuspidata* (SIEBOLD et ZUCCARINI) PLANCHON (ツタ). SFPG no. 43.

Fig. 5. *Myriophyllum spicatum* LINNAEUS (ホザキノフサモ). GSJ F8050.

Fig. 6. *Vitis coignetiae* PULLIAT (ヤマブドウ). GSJ F8051, ×0.9.



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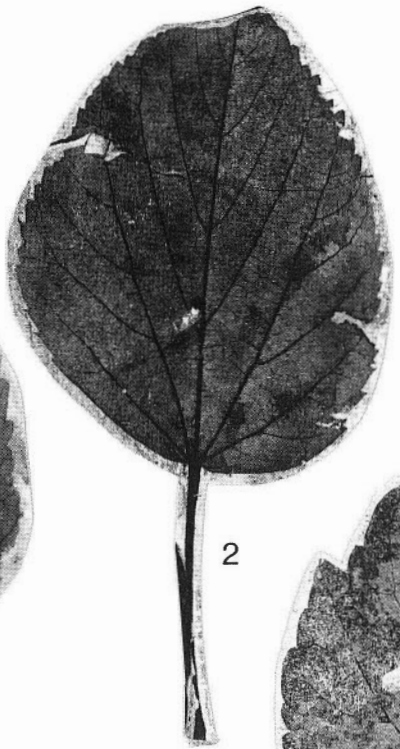

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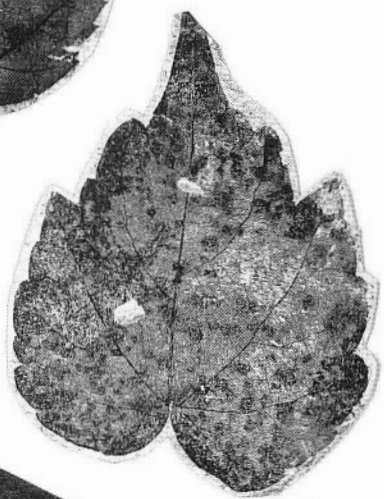

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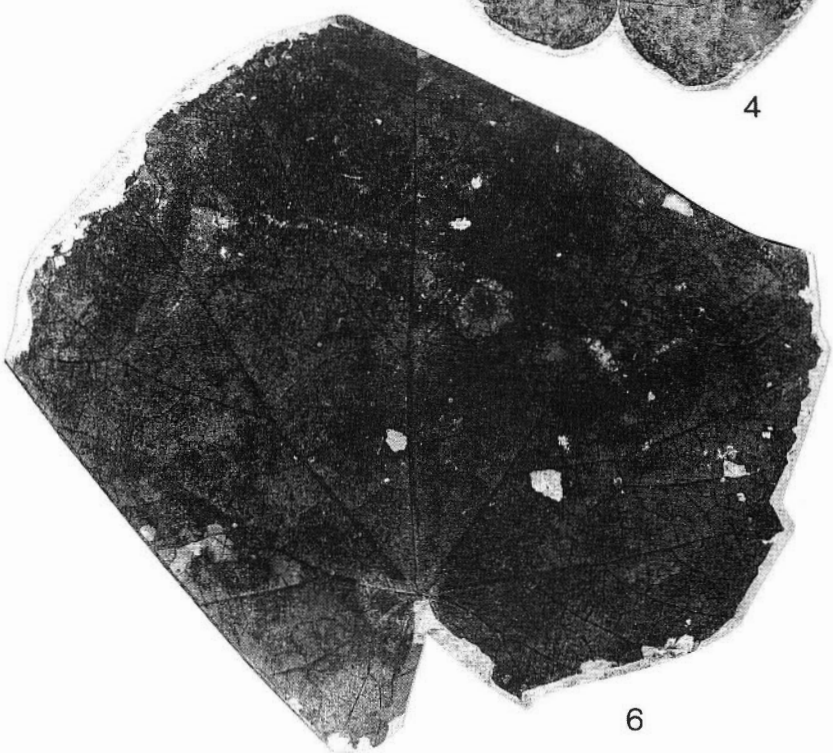

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Explanation of Plate 23
(All figures in natural size)

Fig. 1. *Tilia japonica* (MIQUEL) SIMONKAI (シナノキ). GSJ F8052.

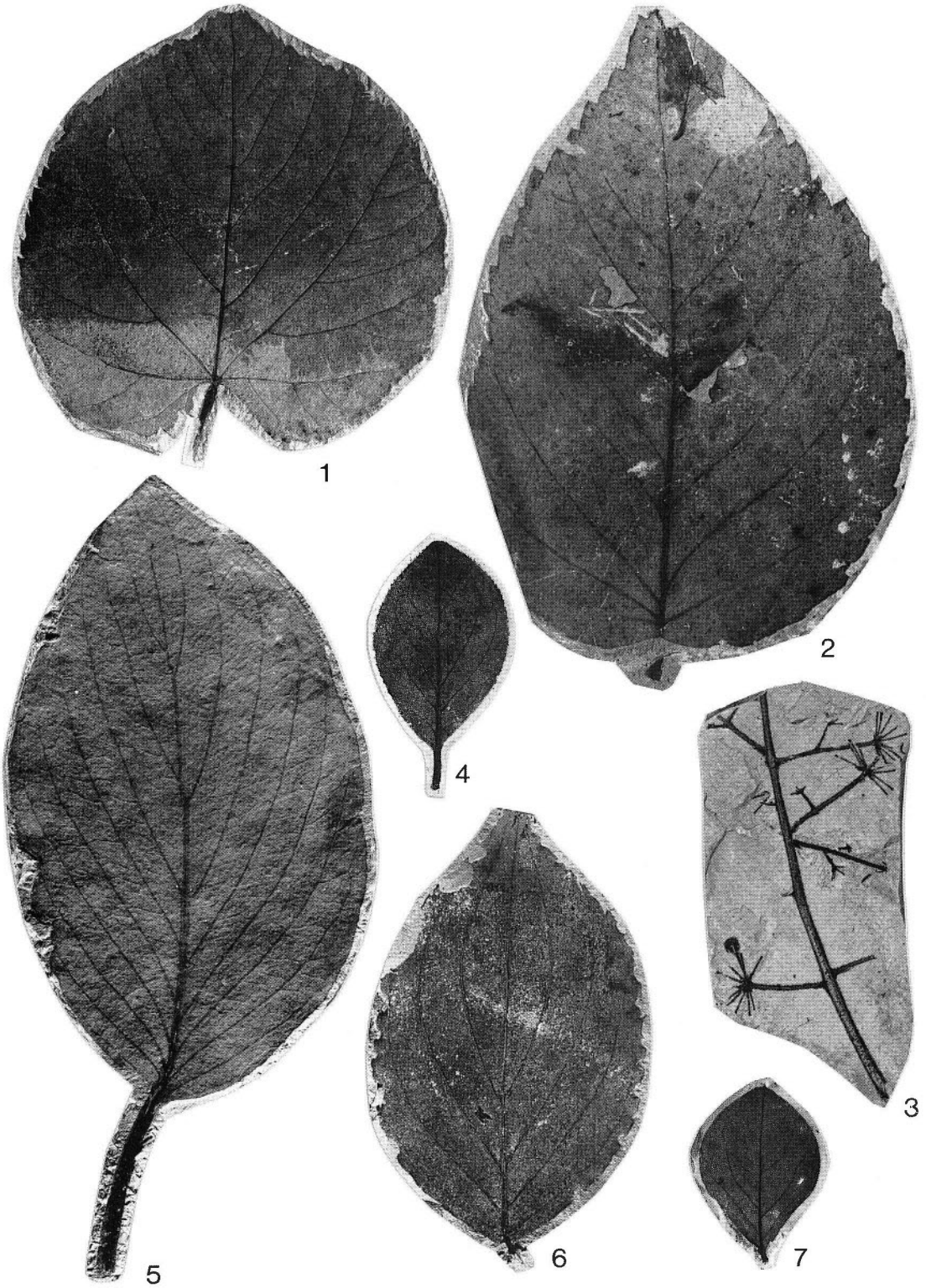
Figs. 2, 3. *Aralia cordata* THUNBERG (ウド). SFPG nos. 147 (fig. 2), 150 (fig. 3).

Fig. 4. *Enkianthus campanulatus* (MIQUEL) NICHOLS (サラサドウダン). GSJ F8057.

Fig. 5. *Cornus controversa* HEMSLEY (ミズキ). SFPG no. 18.

Fig. 6. *Cornus kousa* BUERGER ex MIQUEL (ヤマボウシ). GSJ F8053.

Fig. 7. *Rhododendron quinquefolium* BISSET et MOORE (ゴヨウツツジ). GSJ F8058.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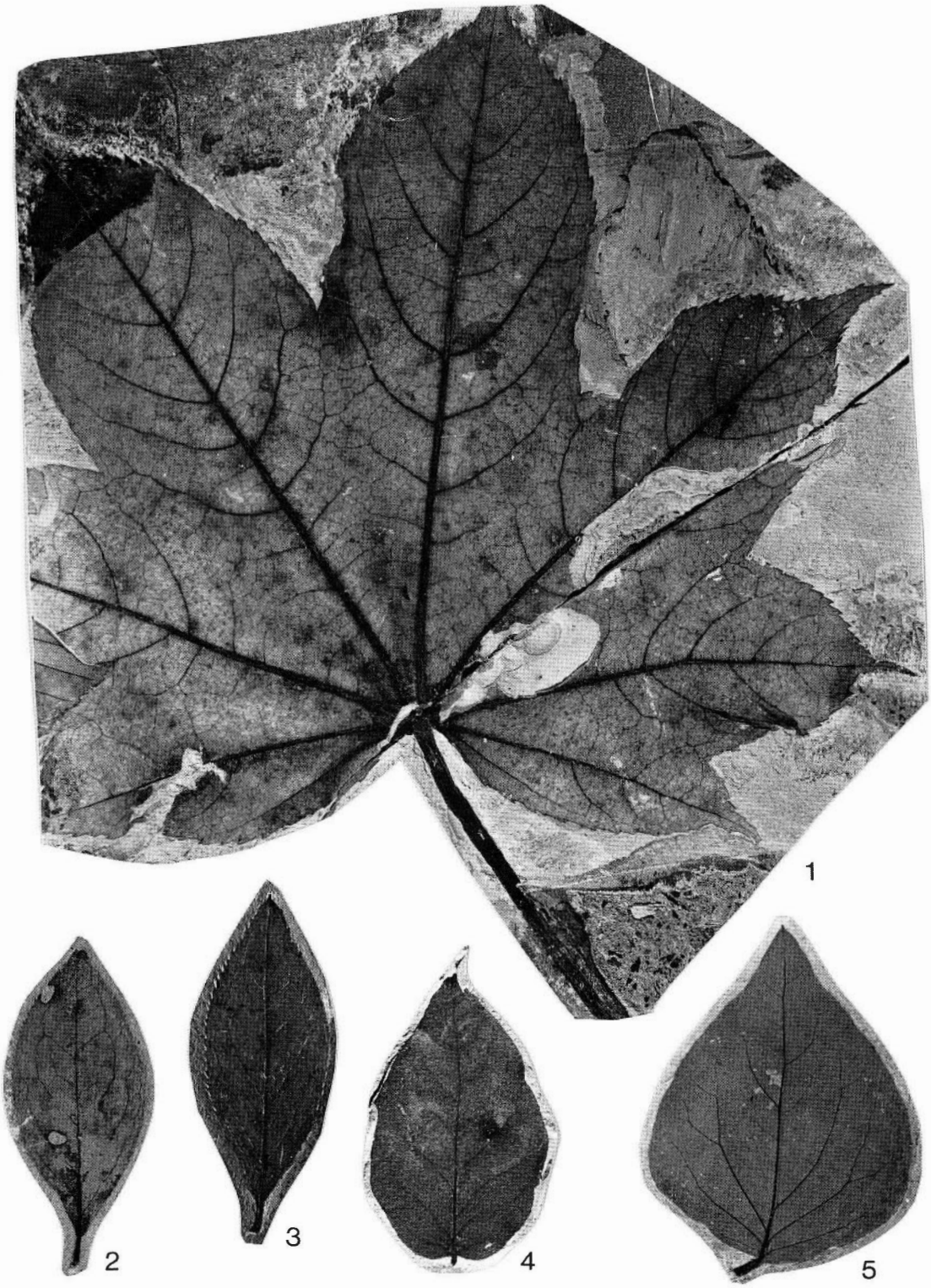
Explanation of Plate 24
(All figures in natural size)

Fig. 1. *Kalopanax septemlobus* (THUNBERG) KOIDZUMI (ハリギリ). GSJ F7541.

Figs. 2, 3. *Rhododendron kaempferi* PLANCHON (ヤマツツジ). GSJ F8054 (fig. 2), 8055 (fig. 3).

Fig. 4. *Lyonia ovalifolia* var. *elliptica* (SIEBOLD et ZUCCARINI) HANDEL-MAZZETTI (ネジキ). GSJ F8056.

Fig. 5. *Rhododendron wadanum* MAKINO (トウゴクミツバツツジ). GSJ F7557.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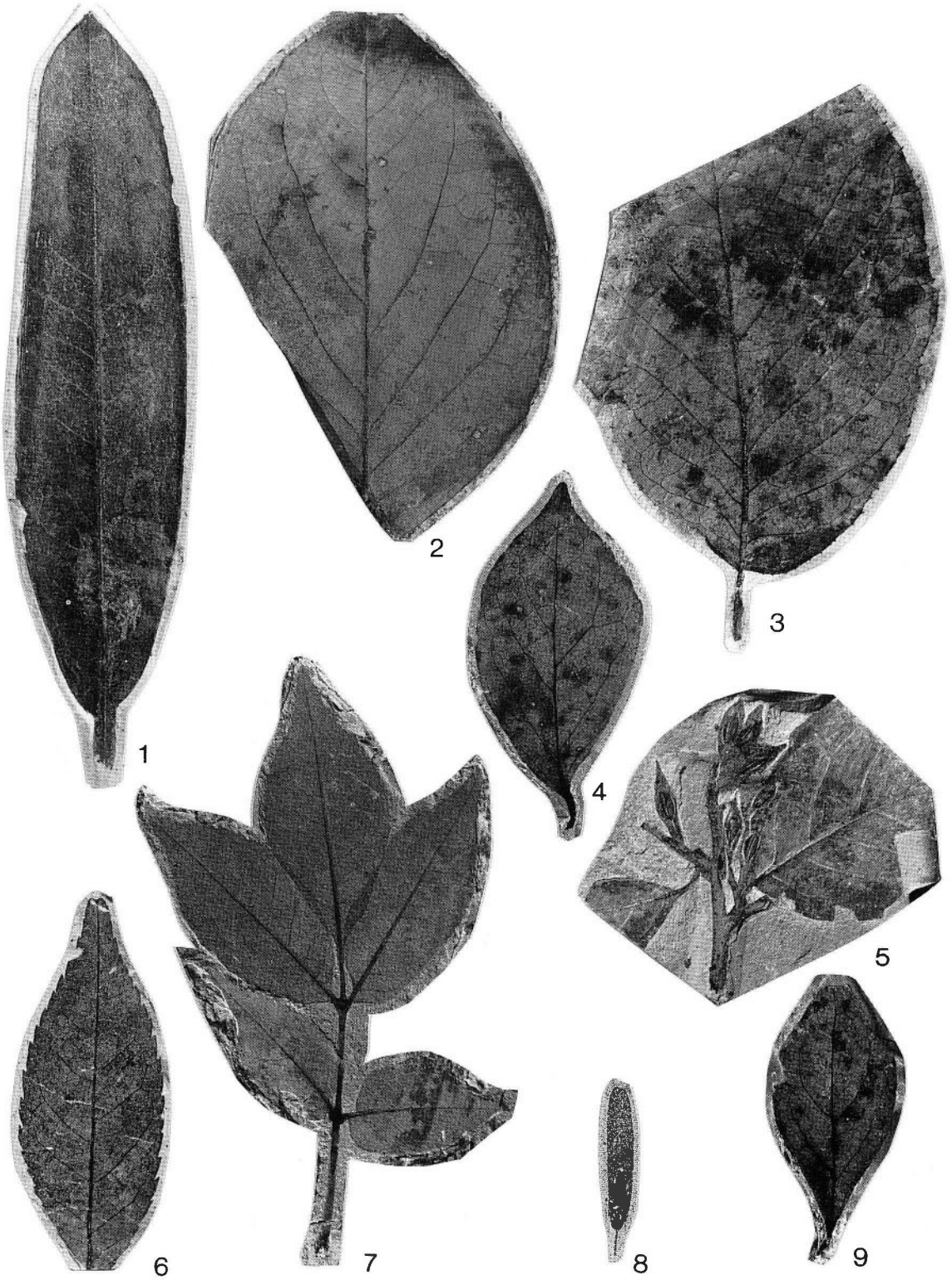
Explanation of Plate 25
(All figures in natural size)

Fig. 1. *Rhododendron degronianum* CARRIERE (アズマシャクナゲ). GSJ F7556.
Fig. 2. *Styrax obassia* SIEBOLD et ZUCCARINI (ハクウンボク). SFPG no. 107.
Figs. 3, 5. *Pterostyrax hispida* SIEBOLD et ZUCCARINI (オオバアサガラ). SFPG nos. 105 (fig. 3), 159 (fig. 5).
Fig. 4. *Styrax japonica* SIEBOLD et ZUCCARINI (エゴノキ). SFPG no. 106.
Figs. 6-8. *Fraxinus lanuginosa* KOIDZUMI (アオダモ). GSJ F8059 (fig. 6), SFPG nos. 108 (fig. 7), 201 (fig. 8).
Fig. 9. *Tripetaleia paniculata* var. *latifolia* MAXIMOWICZ (ホツツジ). SFPG no. 123.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Explanation of Plate 26
(All figures in natural size)

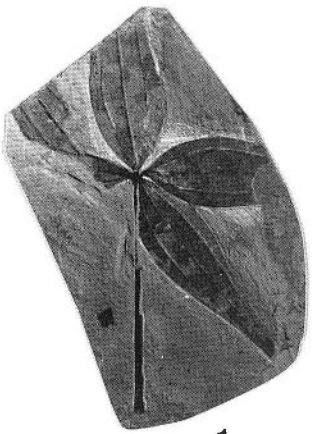
Figs. 1, 2. *Galium kinuta* NAKAI et HARA (キヌタソウ). SFPG nos. 202 (fig. 1), 114 (fig. 2).

Figs. 3, 4. *Clethra barbinervis* SIEBOLD et ZUCCARINI (リョウブ). GSJ F8060 (fig. 3), 8079 (fig. 4).

Fig. 5. *Ligustrum tschonoskii* DECAISNE (ミヤマイボタ). SFPG no. 152.

Fig. 6. *Viburnum furcatum* BLUME (オオカメノキ). GSJ F7532.

Fig. 7. *Acanthopanax sciadophylloides* FRANCHET et SAVATIER (コシアブラ). SFPG no. 99.



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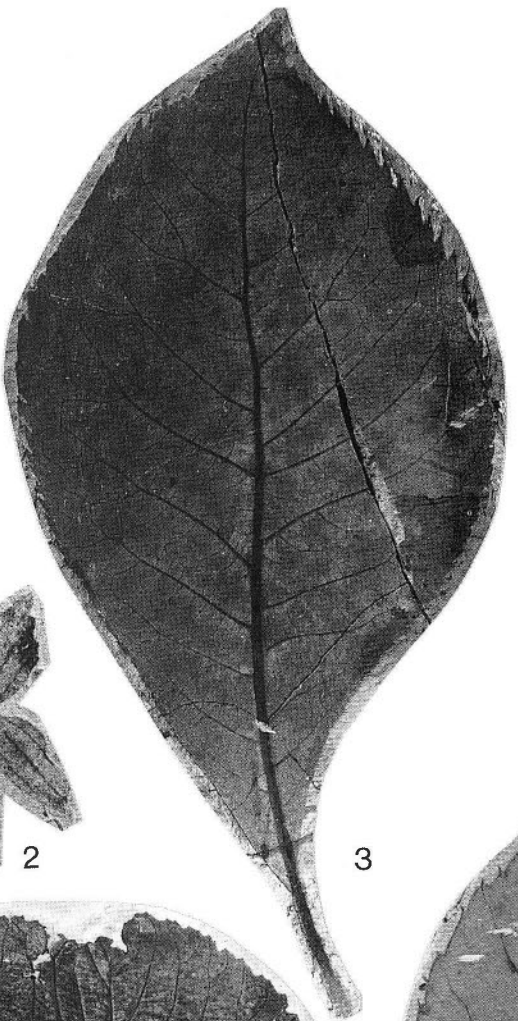

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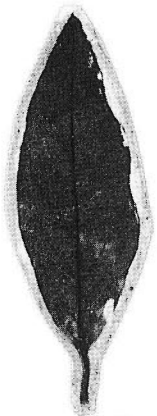

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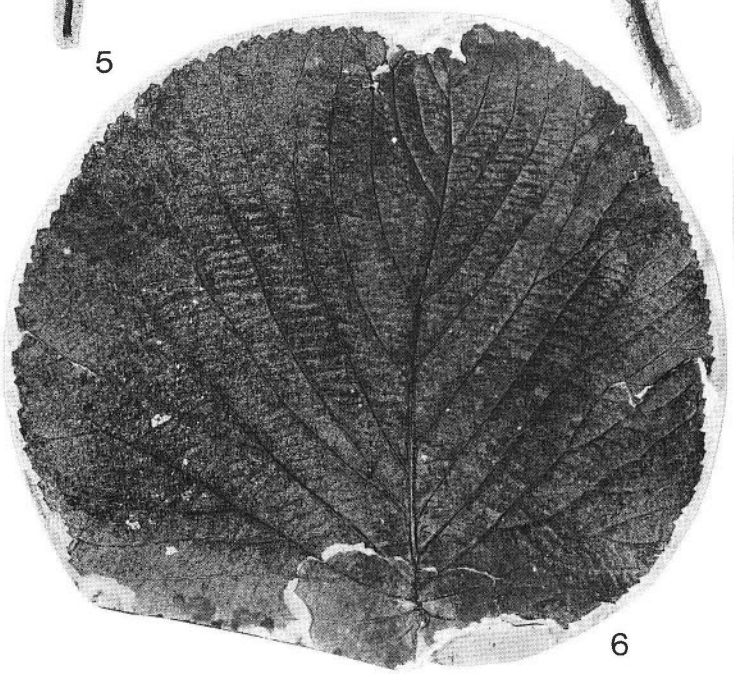

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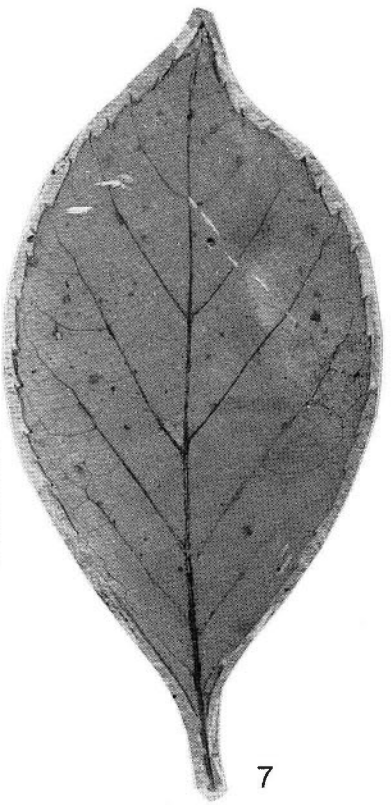

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Explanation of Plate 27
(All figures in natural size)

Figs. 1, 6. *Viburnum dilatatum* THUNBERG (ガマズミ). GSJ F8081 (fig. 1), SFPG no. 206 (fig. 6).

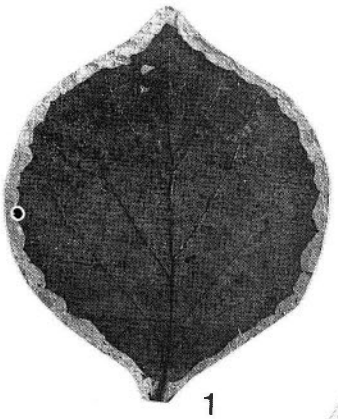
Fig. 2. *Chrysanthemum* sp. cf. *C. makinoi* MATSUMURA et NAKAI (リュウノウギクに比較される種). SFPG no. 148.

Fig. 3. *Viburnum phlebotrichum* SIEBOLD et ZUCCARINI (オトコヨウゾメ). SFPG no. 109.

Fig. 4. *Viburnum wrightii* MIQUEL (ミヤマガマズミ). SFPG no. 20.

Fig. 5. *Viburnum sieboldii* MIQUEL (ゴマキ). GSJ F7558.

Figs. 7, 8. *Artemisia princeps* PAMPANINI (ヨモギ). SFPG nos. 110 (fig. 7), 156 (fig. 8).



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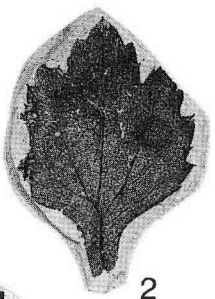

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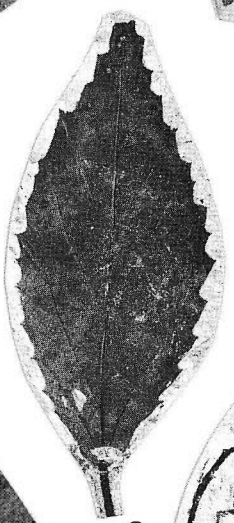

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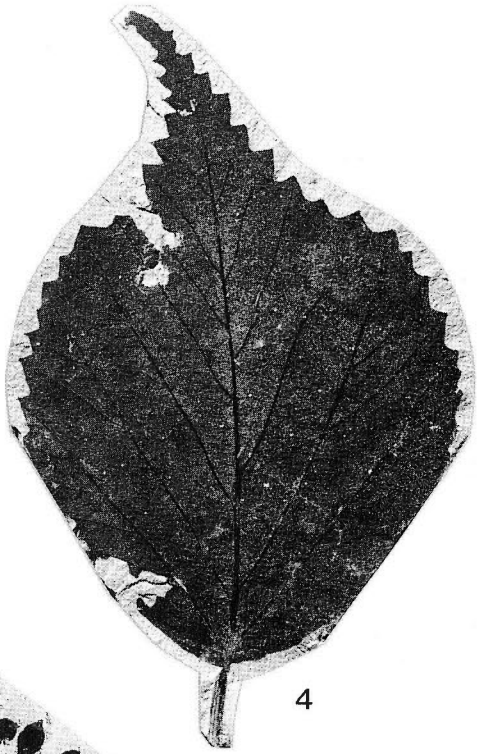

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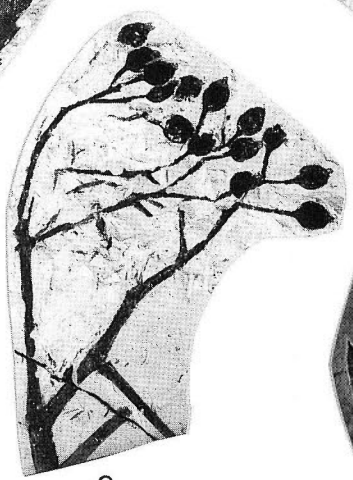

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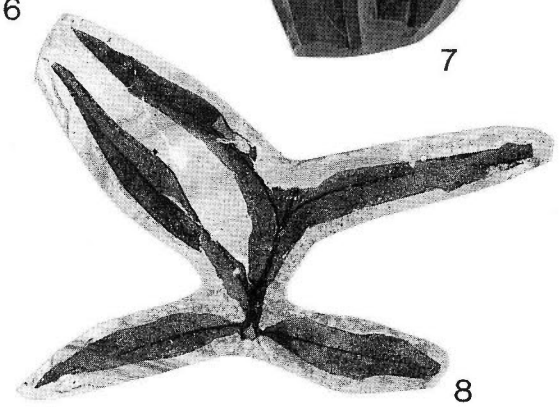

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Explanation of Plate 28
(All figures in natural size)

Fig. 1. *Saussurea* sp. (トウヒレン属の1種). SFPG no. 151.

Figs. 2, 3. *Potamogeton maackianus* A. BENNETT (センニンモ). GSJ F8080 (fig. 2), SFPG no. 111 (fig. 3).

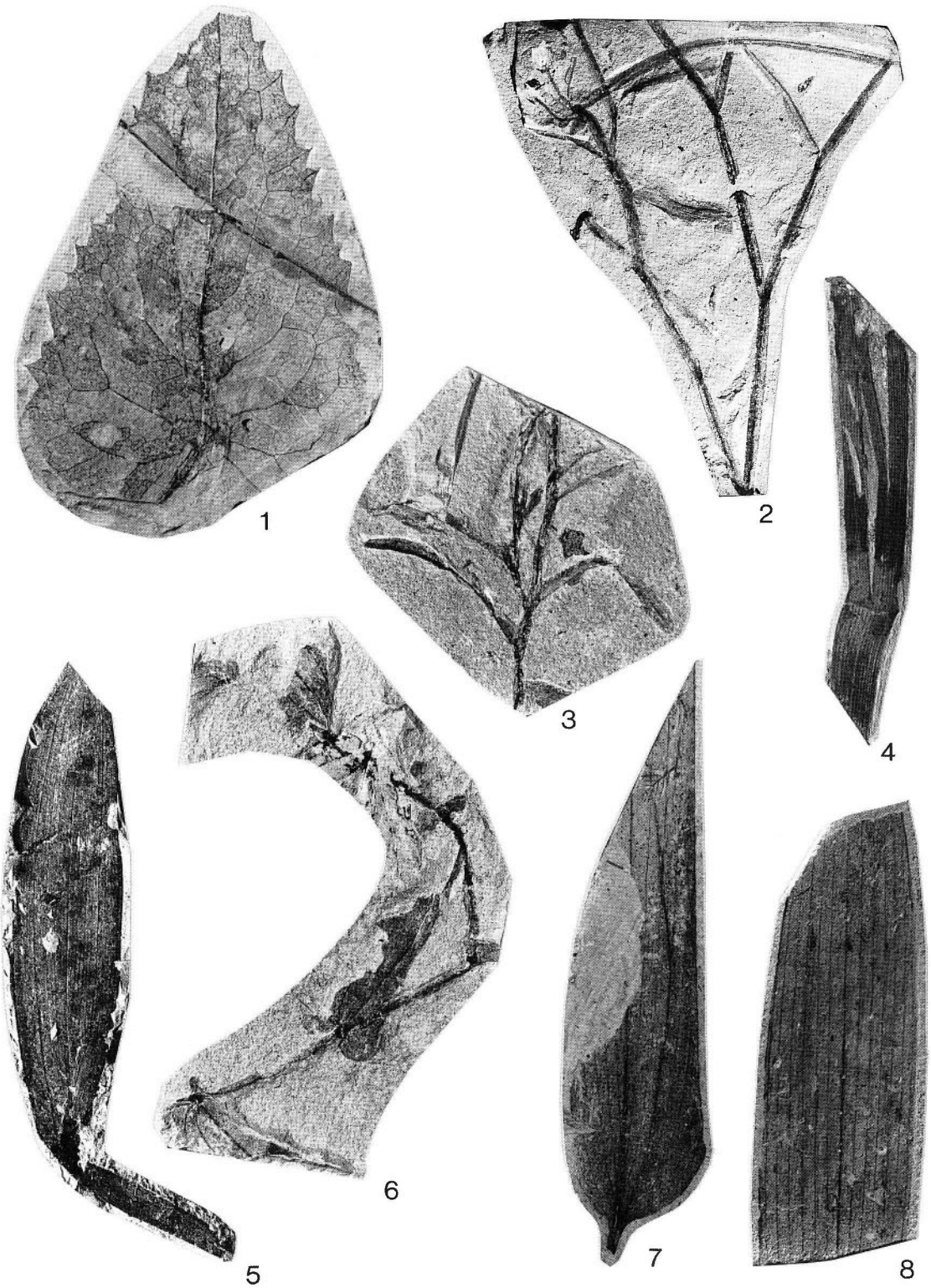
Fig. 4. Gramineae gen. et sp. indet. (イネ科の1種). SFPG no. 136.

Fig. 5. Liliaceae gen. et sp. indet. (ユリ科の1種). SFPG no. 135.

Fig. 6. *Potamogeton perfoliatus* LINNAEUS (ヒロハノエビモ). SFPG no. 112.

Fig. 7. *Sasa* sp. cf. *S. palmata* (BEAN) NAKAI (チマキザサに比較される種). SFPG no. 161.

Fig. 8. *Sasa* sp. cf. *S. kurilensis* (RUPRECT) MAKINO et SHIBATA (チシマザサに比較される種). SFPG no. 204.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Explanation of Plate 29

(Fig. 2 ×500; all others ×700)

Fig. 1. *Abies* (モミ属). Sample no. 1. GSJ F8001.

Fig. 2. *Picea* (トウヒ属). Sample no. 13. GSJ F8003.

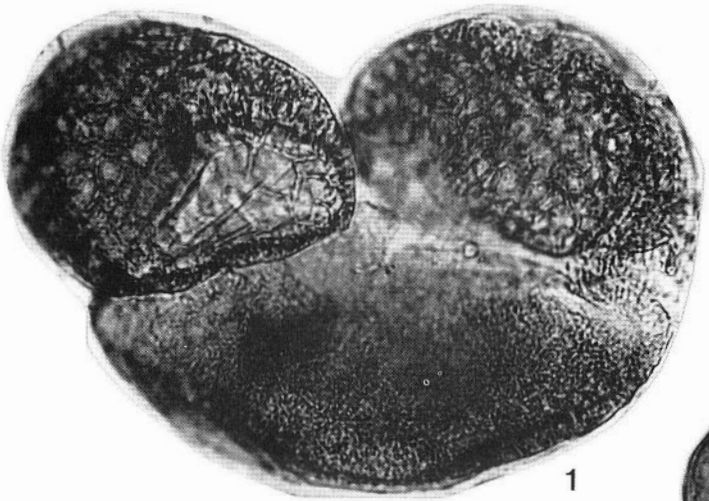
Fig. 3. *Tsuga* (ツガ属). Sample no. 12. GSJ F8009.

Figs. 4, 5. *Cryptomeria* (スギ属). Sample no. 7. GSJ F8012 (fig. 4), Sample no. 3. GSJ F8005 (fig. 5).

Figs. 6, 7. T. C. T. (スギ科・ヒノキ科・イチイ科). Sample no. 13. GSJ F8003 (fig. 6), Sample no. 8. GSJ F8002 (fig. 7).

Fig. 8. *Larix* (カラマツ属). Sample no. 2. GSJ F8010.

Fig. 9. *Pinus* (マツ属). Sample no. 8. GSJ F8002.



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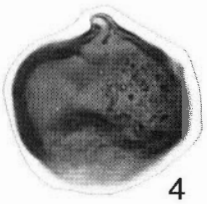

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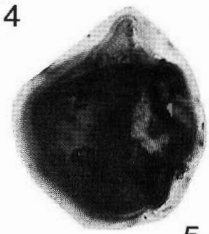

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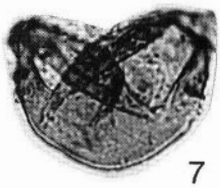

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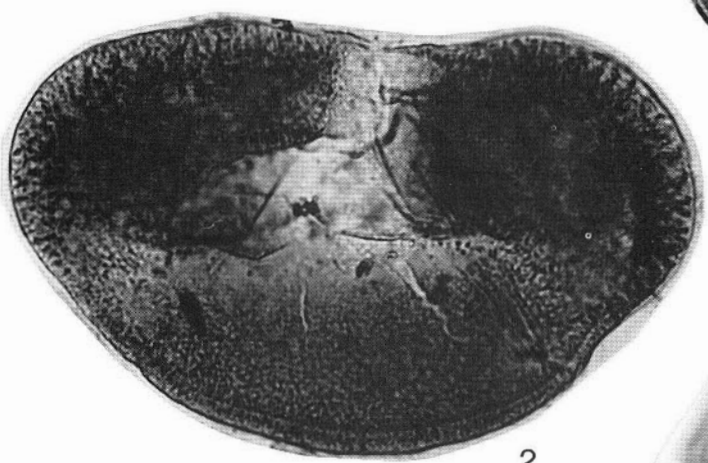

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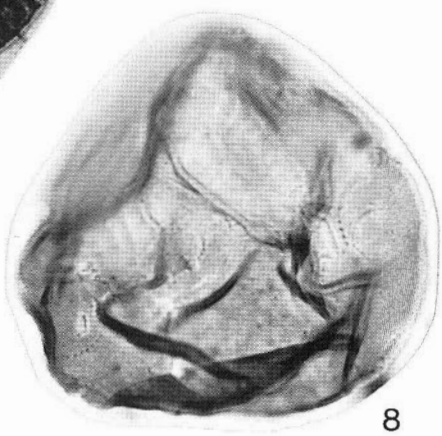

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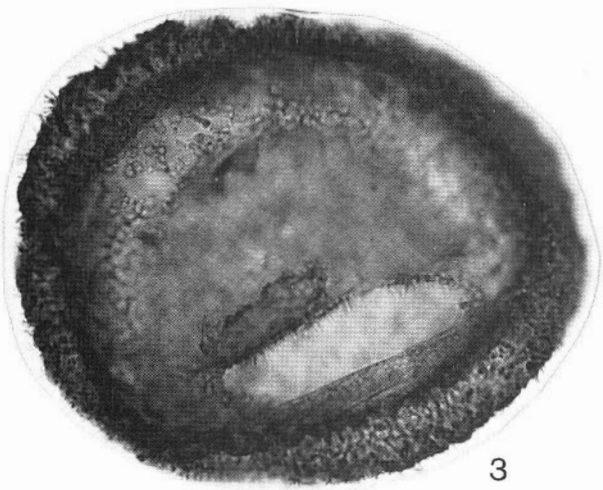

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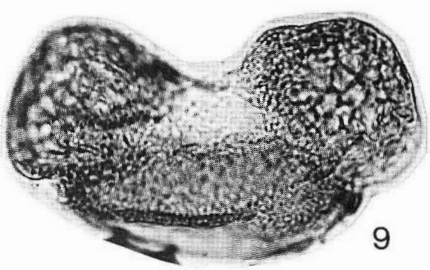

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Explanation of Plate 30

(Figs. 1, 8, 9, 12, 18 ×1,000 ; all others ×700)

Figs. 1, 2. *Juglans* (クルミ属). Sample no. 11. GSJ F8014 (fig. 1), Sample no. 6. GSJ F8007 (fig. 2).

Figs. 3, 4. *Pterocarya* (サワグルミ属). Sample no. 13. GSJ F8003 (fig. 3), Sample no. 3. GSJ F8005 (fig. 4).

Fig. 5. *Salix* (ヤナギ属). Sample no. 8. GSJ F8002.

Figs. 6, 7. *Betula* (カバノキ属). Sample no. 12. GSJ F8009 (fig. 6), Sample no. 1. GSJ F8001 (fig. 7).

Figs. 8, 9. *Alnus* (ハンノキ属). Sample no. 11. GSJ F8014 (fig. 8, 9).

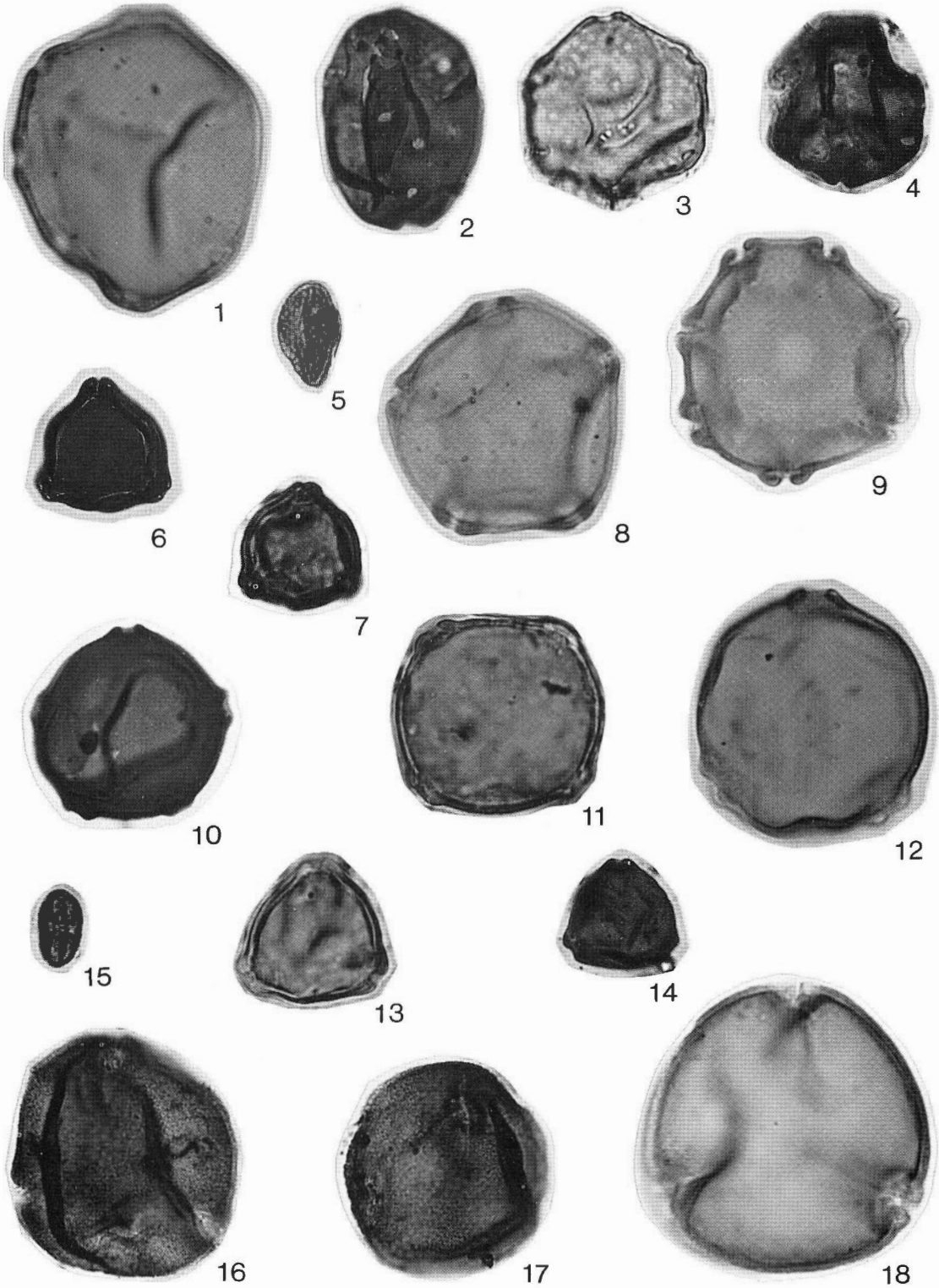
Figs. 10, 11. *Carpinus* (クマシデ属). Sample no. 12. GSJ F8009 (fig. 10), Sample no. 13. GSJ F8003 (fig. 11).

Fig. 12. *Carpinus-Ostrya* (クマシデ属－アサダ属). Sample no. 11. GSJ F8014.

Figs. 13, 14. *Corylus* (ハシバミ属). Sample no. 13. GSJ F8003 (fig. 13), Sample no. 4. GSJ F8006 (fig. 14).

Fig. 15. *Castanea* (クリ属). Sample no. 8. GSJ F8002.

Figs. 16-18. *Fagus* (ブナ属). Sample no. 6. GSJ F8007 (fig. 16), Sample no. 3. GSJ F8005 (fig. 17), Sample no. 11. GSJ F8014 (fig. 18).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Explanation of Plate 31

(Figs. 1, 4, 6, 8 ×1,000 ; all others ×700)

Figs. 1, 2. *Quercus* (*Lepidobalanus*) 〔コナラ属（コナラ亜属）〕. Sample no. 11. GSJ F8014 (fig. 1), Sample no. 6. GSJ F8007 (fig. 2).

Fig. 3. *Zelkova*（ケヤキ属）. Sample no. 13. GSJ F8003.

Fig. 4. *Ulmus-Zelkova*（ニレ属－ケヤキ属）. Sample no. 11. GSJ F8014.

Fig. 5. *Celtis*（エノキ属）. Sample no. 8. GSJ F8002.

Fig. 6. *Euptelea*（フサザクラ属）. Sample no. 11. GSJ F8014.

Fig. 7. Cf. *Corylopsis*（トサミズキ属に比較される花粉）. Sample no. 13. GSJ F8003.

Fig. 8. *Tilia*（シナノキ属）. Sample no. 11. GSJ F8014.

Fig. 9. Ericaceae（ツツジ科）. Sample no. 13. GSJ F8003.

Fig. 10. *Ilex*（モチノキ属）. Sample no. 13. GSJ F8003.

Fig. 11. *Fraxinus*（トネリコ属）. Sample no. 1. GSJ F8001.

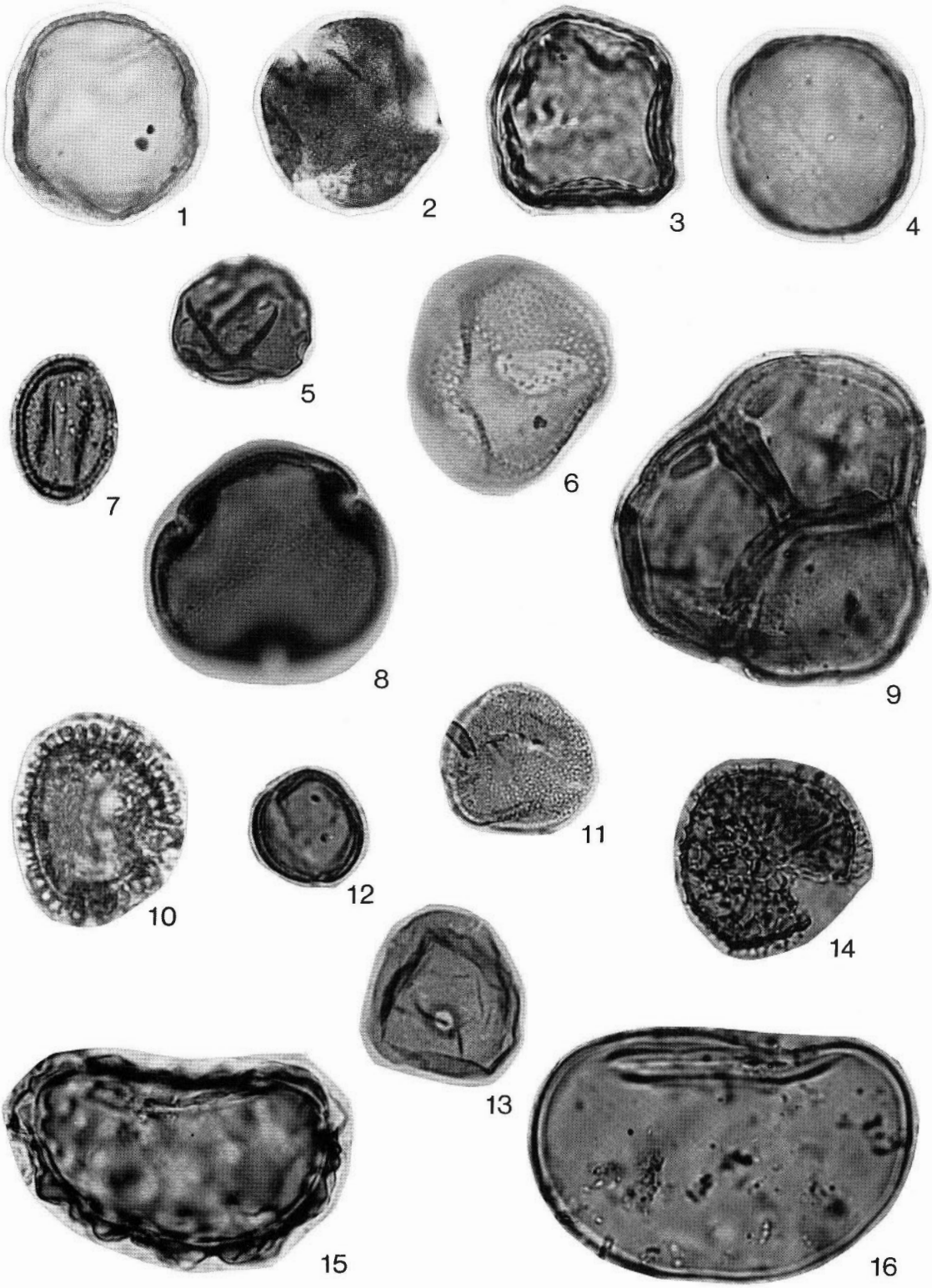
Fig. 12. *Artemisia*（ヨモギ属）. Sample no. 13. GSJ F8003.

Fig. 13. Gramineae（イネ科）. Sample no. 2. GSJ F8010.

Fig. 14. *Lycopodium*（ヒカゲノカズラ属）. Sample no. 1. GSJ F8001.

Fig. 15. Polypodiaceae（ウラボシ科）. Sample no. 13. GSJ F8003.

Fig. 16. Monolete spore（単条型胞子）. Sample no. 13. GSJ F8003.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A. 地質およびその基礎科学に関するもの
- a. 地　質
- b. 岩石・鉱物
- c. 古生物
- d. 火山・温泉
- e. 地球物理
- f. 地球化学

B. 応用地質に関するもの
- a. 鉱　床
- b. 石　炭
- c. 石油・天然ガス
- d. 地下水
- e. 農林地質・土木地質
- f. 物理探鉱・化学探鉱および試錐

C. その他

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A. Geological & allied sciences
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- b. Petrology and Mineralogy
- c. Paleontology
- d. Volcanology and Hot spring
- e. Geophysics
- f. Geochemistry

B. Applied geology
- a. Ore deposits
- b. Coal
- c. Petroleum and Natural gas
- d. Underground water
- e. Agricultural geology and Engineering geology
- f. Physical prospecting, Chemical prospecting & Boring

C. Miscellaneous

D. Annual Report of Progress

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地質調査所：豊肥地熱地域における研究，1985

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地質調査所：地熱情報データベース・システムの研究，1986

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地質調査所報告
no. 269
p. 1-207
1989, 25 fig.,
31 pl., 11 tab.

栃木県塩原産更新世植物群による古環境解析

Palaeoenvironmental analysis based on the Pleistocene Shiobara flora in the Shiobara volcanic basin, cestral Japan.

尾上　亨
ONOE, T.

塩原層群（湖成層）から産する塩原化石植物群は，従来更新世前期の氷期に形成されたとする考えが一般に認められていた．しかし，この化石植物群には温暖な要素が比較的多く含まれていることから，筆者は氷期形成説に疑問をもち，同化石植物群の再検討を行った．研究の手法としては，大型化石（葉・実・花など）171種に花粉化石50種類から得られたデータを加えて，化石堆積当時の気候・環境を推定した．その結果，塩原化石植物群は間氷期に形成されたことが明かとなった．また，その年代は塩原層群中に介在する高原火山の安山岩の全岩によるK-Ar法年代測定値から，約30万年前と推定される．

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Eiji INOUE, Director

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GEOLOGICAL SURVEY OF JAPAN
Higashi 1-chōme, Tsukuba-shi, Ibaraki-ken, 305 Japan
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