A SPECULATION OF THE RHAETO-LIASSIC CLIMATE OF TASMANIA

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ABSTRACT

It is suggested that the flora of the uppermost Triassic and basal Jurassic in Tasmania was a temperate one. This view is suggested by (i) the abundance of bryophytes, (ii) a paucity of vascular plant species, (iii) regular growth rings in petrified woods and (iv) the tendency for the Tasmanian representatives of a given species to be small. The conclusions agree, but not fully, with the conclusions reached from palaeomagnetic data.

INTRODUCTION

Deducing past climates from the fossil plants is difficult and uncertain, except where remains of living species or (sometimes) genera are available (Kräusel 1961, full discussion and literature). When the flora consists of extinct forms argument rests on anatomical features, now found in certain sorts of habitat (and this is not to say that they were always so restricted); and upon the general composition of the flora, using as far as possible the analogy from living plants. It is also unsafe to argue much from the distribution of species now plainly relicts, as *Ginkgo biloba* shows.

The Tasmanian Rhaeto-Liassic flora shows some unusual features and despite the uncertainties just mentioned, it is tempting to apply a climatic explanation, at least as a contributing factor. This explanation may in fact be the simplest. The suggestion is that the Rhaeto-Liassic flora was a temperate one, growing, it may be, in a climate not very different from today.

I am much indebted to Professor H. N. Barber, F.R.S., Mr. M. R. Banks, and Dr. R. Green for much useful criticism. To the managers (or owners) of the several collieries mentioned below I am grateful for permission to collect on their premises.

DISCUSSION

(1) *The limits of the argument.*

The argument is limited to the flora associated with the main coal seams, and of localities believed to be of more or less the same age. According to Hale (in Spry and Banks 1962) the main coal seams lie in the "Feldspathic Sandstone", itself lying at the top of the Triassic succession, e.g., in the Brady Formation of McKellar (pp. 226-229). This agrees with evidence from megaspores (below, and Hale *loc. cit*, pp. 224-226).

The plant fossils come from the localities listed on p. 15. Some of these have been dated as belonging to the zone of *Lepidopteris ottonis* (Upper Rhaetic) and of *Thaumatopteris schenki* (basal Liassic) by Dettman (1961). These are Langloh, the Cornwall mine in general and Barbers mine. Others, such as the Merrywood open cut, Dalmayne and the upper Douglas River, lie close to the dated localities, in the same suite of rocks and are almost certainly the same age. Yet others, however, e.g., Pateena and Forster Street, Hobart, lie at a distance from a dated locality and their date is not securely fixed. Some indeed (Prices Jetty, Mt. Christie mine) contain plants absent or very rare in the rest of the localities, and these localities may be slightly older than the others. Some which are almost certainly a good deal older (e.g., St. Virgils), or from which good material is no longer available (see Johnston 1883), are excluded altogether.

It is thus assumed that the flora discussed is mostly of Rhaeto-Liassic age, and any part not this age, only slightly older.

A limitation inherent in the evidence is that only that fraction of the flora that grew near where it is now fossilised is available. We know nothing of the upland flora of Tasmania in the Triassic, and very little from anywhere else (Harris 1957).

(2) *Floras for comparison.*

The standard Rhaeto-Liassic flora is found in the sea cliffs at Scoresby Sound, East Greenland, and it is well known (Harris 1937, discussion and references). The fresh-water beds with plants overlie red beds (representing the final stages of the terrestrial phase of erosion following the Hercynian orogeny) on a level surface, and themselves were laid down by (probably) several rivers at or about sea level. The fresh-water sequence is followed by marine rocks. Contemporaneous floras, with similar histories and depositional conditions are found in Sweden (Troedsson 1938, Lundblad 1950, 1959), Germany (Gothan 1914, Jung 1960) and Poland (Racibroski 1894 for macrofossils), and the general history of the area is given by Gignoux (1950, especially pp. 214, 278-280, fig. 59). There are two main differences from Tasmania; the fresh-water sequence overlies desert beds, but in Greenland at least, there is evidence (Harris *loc. cit.* p. 101) that there was abundant water at the time the flora grew; and the fresh-water beds are overlain by marine, and this may not be important. In Greenland coal is present, but the seams are thin and impersistent; in Sweden, however, the seams are thick and workable. The parallel with Tasmania is not exact, but is close, and comparison would appear to be just.

The best known Mesozoic flora is that of the Bajocian and Bathonian in east Yorkshire (see Arkell 1933, pp. 313 *et sec.*, Harris 1952). This fresh-water sequence of deltaic origin, is both under- and overlain by marine beds. A longer time interval is covered, but there is little evidence of macrofloral change between the oldest and youngest plant beds. Comparison is made with this flora too, but there may have been differences in conditions of depostion.

It is difficult to obtain a southern flora for comparison. Three are possible, Ipswich (see Jones and de Jersey 1947), the Molteno (see Du Toit 1927) and the floras of the Argentinian Pre-Cordilleras (Frenguelli, e.g., 1943, 1947), but all present difficulties. There is no modern account of the Molteno flora, and the Molteno is probably mostly Middle Triassic (Watson in Townrow 1957). In the Argentine Frenguelli deliberately rejected microscopic data (1943 p. 227), which vitiates his identifications, and it seems clear that his floras range over a longer time than the Tasmanian ones. The Ipswich is perhaps the most useful, but here too Jones and de Jersey were hampered by lack of suitable material, and the Series covers a longer time than the Tasmanian Rhaeto-Liassic.

Admittedly, the Tasmanian flora needs revision, but this only makes it more important to compare with well-known floras. It also has the effect of rendering all conclusions tentative, but in the matters in which comparison is made below (especially numbers of species) the disparity between the floras compared is great.

(3) *Depositional environment.*

Hale (*loc. cit.* pp. 230-231) makes it clear that the Triassic in Tasmania is a fresh-water deposit, and it seems plain from the depositional structure, as from the existence of thick coal seams and a copious flora, that water was abundant. The only possible evidence to the contrary is deposits of gypsum along the bedding planes, seen locally lower in the succession. Tasmania at this time also formed a low-lying area, comparison is made with the Florida Everglades.

(4) *Characters of the flora.*

(*a*) The proportion of Bryophyles.

Eight species of liverworts and two mosses can so far be recognised in Tasmania, I supect there may be more, while the number of vascular plant species is, very tentatively, twenty-five to thirty. The Tasmanian figures are most unusual. The number of bryophytes is high both absolutely and in proportion. In Greenland there are four species of liverwort, but 160-180 of vascular plants. In the Yorkshire flora there are four (possibly six) liverworts known, but thirty ferns (Harris 1960) and some twenty-three conifers (Florin 1958), not counting other groups.

The only floras that compare are the Permain ones from the north of the U.S.S.R. (Neuburg 1960) in which there are ten or so species of mosses known. These floras, however, extend over most of the Permian, but the Tasmanian ones are contained in two zones only.

Most fossil bryophytes are rare, except the mosses just mentioned, and also *Naiadita*, which, however, grew in a rather special water habitat (Harris 1937); but in Tasmania, though they are only found in the finest grained deposits (a general feature of fossil bryophytes) they are not rare—there are thousands of specimens.

At the present bryophytes are commonest in cool moist climates or, in the tropics, on mountains (e.g., they are very abundant in the Himalayas). Since the Tasmanian environment was not mountainous, it would seem to follow that it was probably cool and moist. Neuburg (1960) uses a similar argument for her floras. It might be argued that the fossils have been carried from mountains to their present resting place, but the fact that delicate hairs and scales may be found rules this possibility out. Müller (1954) discussing liverwort distribution points out, however, that the Marchantiales and Jungermanniales Anacrogynae are less exacting than the Acrogynae, but it is to the Marchantiales and (probably) Jungermanniales Anacrogynae that the Tasmanian fossils belong.

(*b*) The number of species of vascular plants.

At a first and very provisional estimate the number of species of vascular plants can be allocated as follows:—

- Marattiaceae—one species (usually given under *Taeniopteris*)
- Osmundaceae—five species (the *Cladophlebis australis complex*)
- Corystospermaceae—seven species (of leaf)
- Ginkgoales—two species (one *Ginko*-like, one *Czekanowskia*-like)
- Equisetales—one or two species (of *Equisetum*)
- *incertae sedis*—*Phoenicopsis elongatus* (probably two species); *Linguifolium* and its allies (two species).

There are some notable absentees. No cycadophyte leaf is known from the flora discussed here, though *Pterophyllum* is known from lower in the succession. The only Triassic conifer known to me is a single shoot from a locality (Stonehenge) that may be older than any given here.

Fossil plants are not scarce, however. A good locality will bear comparison, for mere production of fossil matter, with some of the classic localities such as Cayton Bay. It is that only seven or eight species reward a week's search, instead of twenty or thirty. In fact, though not all the records are critical, this paucity of species appears in earlier accounts of the Triassic.

An impoverishment in species, but continuing abundance of individuals is characteristic of floras passing polewards: it is striking in Europe (Good 1947), and can be seen fairly well in some groups, such as ferns, today in Tasmania. It may be that the same phenomenon is seen in the Rhaeto-Liassic of Tasmania. There are two arguments against this idea. The first is the absence of conifers. This is an important but not a conclusive argument. It is true that at the present conifers are mainly a temperate group but (i) the Order is now something of a relict, but it was not in the early Mesozoic, and (ii) though mainly temperate the numbers of species and genera do fall off towards the poles, so that the chief poleward extensions beyond Lat. 55° are composed of rather few genera and species (Florin 1963). The second argument is that there are no specifically temperate groups to be seen in the Tasmanian flora, though on the analogy from the present they would be expected; this may be no more than to say that the flora is as yet incompletely known.

The paucity of the Tasmanian flora is in marked contrast with the Northern Hemisphere floras (authors given above), and, so far as comparison is possible, it contrasts with the Ipswich, Molteno and the Argentine. A point to note, however, is that it also contrasts with the *Middle* Jurassic flora of Antarctica (Halle 1913).

In the case of the ferns direct comparison of fertile leaves is possible, as follows:—

Tasmania:
- Marattiaceae—one species
- Osmundaceae—five species (six)

Greenland:
- Marattiaceae—two species
- Osmundaceae—six species
- Gleicheniaceae—one species
- Dipteridaceae—seven species
- Matoniaceae—three species (nineteen)

Yorkshire:
- Marattiaceae—one species
- Osmundaceae—five species
- Dipteridaceae—
  - Dipterideae—one species
  - Camptopterideae—two species
- Matoniaceae—five species
- Schizeaceae—two species
- Dicksoniaceae—
  - Dicksoniea—two species
  - Thyrsopterideae—eight species
- ? Aspideae—one species (twenty-seven).

The Greenland and Yorkshire floras are compared from an evolutionary point of view by Harris (1956). Lack of information on the fertile fronds makes comparison with other southern floras impossible.

At present both the Marattiaceae and Osmundaceae are relict Families, and little can be deduced from their present distributions. In the early Mesozoic, however, both were world-wide. The present day distributions are, Osmundaceae, temperate or tropical montane (Holttum 1950), Marattiaceae, tropical, but with extensions to New Zealand and Japan (Copeland 1947).

(*c*) Evidence from growth rings.

The classical indicator of a temperate climate is the presence of growth (annual) rings in the fossil woods available. Thus regular growth rings are seen in the petrified woods of Tasmania and southern lands in general during the Permian (e.g., Seward 1913, Seward and Walton 1923) when other evidence indicates a cool climate. There is little petrified wood available from the Tasmanian Rhaeto-Liassic, two coniferous-type trunks are present in the bed of the Douglas River above the third coal seam (going upstream) and I am indebted to Mr. M. R. Banks for telling me of others from Catamaran and South Cape Bay. This material is not well preserved and specifically indeterminable, but it does show prominent and regular growth rings, indeed, this is one of its most obvious features. In this it resembles, as noted, the Permian woods, and it is interesting that the rings look more regular than those of the Jurassic Rajmahal woods from India (Sahni 1931, Bhardwaj 1953, Suranarayana 1955).

The formation of growth rings is a most complicated matter (see Studhalter 1955, Glock 1955 for reviews and literature), for some plants (e.g., cycads) never seem to have formed growth rings, and growth rings can continue to be formed when the (supposed) conditions that lead to their initiation have vanished. Also causes such as a sudden access of light, as when an old tree falls, can lead to variation in growth ring pattern. It seems well established, however, that *regular* growth rings in *conifer type* woods are formed under cool moist conditions with a short growing season, the rings becoming less regular and more varied in nature going towards warmer dryer regions (Glock and Agerter 1963).

(*d*) The size of Tasmanian fossils.

Any comparison in size depends upon an accurate taxonomical treatment, which is scarcely possible yet. Among the Corystospermaceae, however, the leaf *Dicroidium odontopteroides* (taken to exclude *Thinnfeldia obtusiloba, T. acuta* and *T. supberba,* see Townrow 1957) is probably the leaf of one plant. From Umkomaas in the Molteno forty specimens had an average length of 7.5 cms., but thirty-five leaves from the old Mt. Christie mine han an average length of 5 cms. In the small populations available to me Tasmanian specimens of *Dicroidium feistmanteli,* and *"Reinitsia" spathulata* are smaller than specimens from elsewhere.

Leaf size also is a most complex matter involving an interplay between genetic and other factors in a given individual (see e.g., Stebbins 1950, pp. 40 *et seq.* for discussion and references). However, (i) within the same species populations showing small leaves (and a dwarf habit) tend to be found at higher latitudes and altitudes (Clausen, Keck and Hiesey 1948). Another point is that (ii) leaves produced when water is less plentiful tend to be small either on the same individual, or in different populations (e.g., Yapp, 1912, Salisbury 1927). Further (iii) many plants produce a succession of leaves of different sizes during the growing season. The small size of a leaf may be caused by its having fewer cells (as in high latitude populations), or smaller cells (as in "drought" leaves).

In the present connection the population as a whole is considered since it is impossible to say which plant produced which fossil leaf, and this tends to rule out consideration of the second and third factors above. As noted, the evidence suggests that water was plentiful (though many bog plants today show xeromorphy). This leaves the effect of high latitude and high altitude. But the altitude was not high. The final possibility is therefore, that the latitude may have been.

(*e*) Abscission scars.

All the seed plants in which the leaf base is known show a structure looking much like, and interpreted as, an abscission scar (Townrow 1960 for discussion of appearance). This might mean that the leaves were deciduous, and the demonstration of an abscission scar is a necessary preliminary to showing that a fossil leaf was deciduous. On the other hand it might mean that the leaves were shed at intervals of several years, like the shoots (and needles) of many conifers. In any case, deciduous plants are not all temperate, neither are all temperate plants deciduous. On account of these considerations no argument is attempted on this point. Similarly, nothing is argued from the cuticular structure of the seed plants (actually it is rather varied in things such as sinking of the stomata), because until it is known whether the plants were deciduous or not no useful conclusion can be reached. Deciduous leaves only reflect conditions in the growing season.

I am unable to apply Dr. Plumstead's argument (1958). She points out that *Glossopteris* leaves occur in great abundance (leaf banks), but that the putative stems of these plants are rare, and from this deduces that the Glossopterideae were deciduous and probably temperate. They probably did grow in a temperate climate, but this evidence is not good enough. Almost any Mesozoic plant shows an apparent super-abundance of leaves, and the explanation almost certainly is that leaves and stems float differently, and so are found fossil in different places. Also an abscission scar has not been demonstrated yet for *Glossopteris* and its allies.

(5) *Consideration of other evidence.*

Paleomagnetic data (see Cox and Doell 1960, Irving, Robertson and Stott 1963 for summaries) suggests that throughout the Mesozoic Eastern Australia lay nearer the south geographic pole than it is today, and for the Middle Jurassic Tasmanian Dolerites (McDougall 1961, Evernden and Richards 1962), the pole is placed at (approximately) 51°S and 160°E: the present position of Hobart being, to the nearest degree, 43°S and 147°E. On the other hand the floras with which comparison is made are all further from the (then) pole, and in the case of the European ones, almost tropical (e.g., pole position Yorkshire, Jurassic, 85°N and 150°E). The exception is the Russian Permain, which may have been at a higher latitude (Cox and Doell 1960, p. 708), possibly warm temperate, and it is interesting that in respect of its bryophytes the Permian floras are somewhat comparable with the Tasmanian ones. At first sight agreement appears to be good.

On consideration difficulties arise. At present there is no flora at a comparable latitude South, at the same latitude North there may be a considerable one, but except for an area in north Russia, 70°N is beyond the limit of trees (Polunin 1959). But large trees occurred in the Tasmanian Rhaeto-Liassic. Judging from the present (but see above p. 8) it is totally unexpected to find the Marattiaceae and Osmundaceae forming a considerable element in the flora.

The difficulty might be met by arguing that the present world climate, interglacial, is abnormally cool. In a non-glacial time (i.e., in absence of permanent polar ice) the world climate might be warmer, at least at high latitudes once the very great influence of the ice caps was withdrawn. The problem is discussed by Lamb (1961) who gives many references. A different distribution of land and sea around Tasmania would also affect climate.

Another argument might be that the extensive floras from both Arctic (Andrews 1961) and Antarctic (Plumstead 1962) indicate that plants could grow in these places, now impossible for most of them. If, however, it is once allowed that the position of the poles has not been constant, this argument is embarrassed by uncertainty whether the past latitudes of the polar regions are comparable with the present.

It seems to me that there is agreement between evidence from fossil plants and palaeomagnetic data only up to a point. Both agree that Tasmania in the Rhaeto-Liassic was not tropical, the plants a cool temperature climate, the palaeomagnetic evidence a latitude more consistent with an arctic climate.

CONCLUSIONS

The thesis that in the Rhaeto-Liassic Tasmania enjoyed a cool temperate climate has several lines of evidence to support it. However, it is not claimed that any is conclusive, and though they reinforce one another, the matter remains a suggestion. At best it might be taken as a useful working hypothesis.

It would perhaps be thought better to wait for more localities and species. I suspect this would be a wait in vain. Doubtless new species will be added, but a glance at the list on p. 5 shows that Triassic localities are not getting more numerous, and with the decline of the coal mining industry, are unlikely to do so.

Axelrod (1952) has suggested that the early Angiosperms evolved on the warm to tropical Permo-Triassic uplands. If so, it is unlikely, on the present arguments, that their remains will be found in Tasmania. Perhaps eastern Australia in general will not be the best place to look for them.

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APPENDIX

List of localities from which material has been utilised.

Derwent Valley—

Langloh coal mine:
- worked seam*
- upper seam*

Ouse River, cliff 3 miles N.W. of Ouse

Fingal Valley—

Cornwall coal mine†:
- loco section*
- main road (*a*)
- main road (*b*)

Jubilee open cut:
- lower seam, floor*
- upper seam, roof shales*

Jubilee mine, dump*
Barbers mine†:
- old tunnel*
- new tunnel

Duncan mine, dirt band near roof*
Yeats mine, chitter from dump*
Merrywood open cut:
- roof shales
- shales 20-30 ft. above seam

Old Mt. Christie Mine:
- black shale
- in seam*

Stanhope mine, dirt band*

East Coast—

Douglas River:
- lower seam*
- top seam, dirt partings

Dalmayne mine, dirt partings
Creek (un-named) near Gray P.O., creek bed*

Tasman Peninsula—

Prices Jetty, shales on foreshore

North—

Pateena mine, dump

Hobart—

Forster Street brick pit*

NOTE.—The above list is not exhaustive, but includes a high proportion of the localities yielding *good* fossil plants.

* Denotes that the locality is extinct.

† Considered as separate localities, though on the same general horizon, because the localities are separated by several hundreds of yards of (somtimes) barren shale. The plant-bearing shales lie in a band up to 16 ft. thick above the worked seam, and it is likely that not all material comes from the same level within this shale band.