JURASSIC FLORAS OF THE KARATAU RANGE, SOUTHERN KAZAKHSTAN

by M. P. DOLUDENKO *and* E. R. ORLOVSKAYA

ABSTRACT. A series of six rich floras, containing about 180 plant species, is known from the upper part of the Lower Jurassic (Upper Liassic), the Middle Jurassic, and the Upper Jurassic of Kazakhstan. An analysis of the composition of these floras reveals gradual changes which may be correlated with changes in the climate and palaeogeography of the region. The data on Upper Jurassic megafossil floras is compared with that on their spores and pollen.

THE study of Jurassic floras of the Karatau Range (southern Kazakhstan), a north-western spur of the Tien Shan Mountains, began about 50 years ago in connection with intensive research on Jurassic deposits and prospecting for coal in this region. Palaeobotanical materials from the Karatau were examined by Romanovsky (1890), Seward (1907), Brick (1925*a–c*), Turutanova-Ketova (1929, 1930, 1936*a*, *b*, 1950, 1963), Prinada (in Buvalkin 1958), Vakhrameev and Yaroshenko (1958), Romanova (1961), and Murakhovskaya (1968). In the 1960s Sakulina, studying spore-pollen assemblages from Jurassic deposits of the Karatau Range, noticed that the correlation and dating of Jurassic strata, particularly of those from the Lower and Middle Jurassic, were not precise enough. She invited Orlovskaya to take part in analysing the floristic materials. Shortly after, Doludenko, who had formerly studied the Callovian[1] flora of Georgia (Doludenko and Svanidze 1968, 1969) turned to studying the Upper Jurassic flora of the Karatau. (The collections containing the flora described by Orlovskaya from the upper Lower Jurassic–Middle Jurassic are kept at the Institute of Zoology of the Academy of Sciences of Kazakhstan S.S.R. in Alma-Ata; those of the Upper Jurassic flora described by Doludenko are kept at the Geological Institute of the U.S.S.R. Academy of Sciences in Moscow.) A monographic description of the Jurassic floras of the Karatau will be published in the Transactions of the Geological Institute of the Academy of Sciences of the U.S.S.R.

Study of the Karatau Jurassic floras is of a great practical importance, as it can help to work out a general stratigraphic scheme for this region, and it also throws light on Jurassic floras in general.

The work of Turutanova-Ketova on the Upper Jurassic flora of the Karatau is particularly noteworthy. We know very few Upper Jurassic floras within the Indo-European palaeofloristic area, because in the Late Jurassic the climate became much more arid throughout much of Europe, Kazakhstan, and Middle and Central Asia. Such floras as have been described are from Scotland, France, India, Japan, and the U.S.S.R. (Georgia and the Gissarian Range). The Jurassic flora of the Karatau grew on the bank of a lake (Gekker 1948) and was buried in lake sediments, unlike those of Scotland, France, and Georgia, which were sea-coast floras.

The Karatau Range stretches over 400 km from south-east to north-west. It is subdivided into the Bolshoy and Maly Karatau, the latter being subparallel to, and

[1] The Callovian is placed, by geologists of the U.S.S.R., in the Upper Jurassic.

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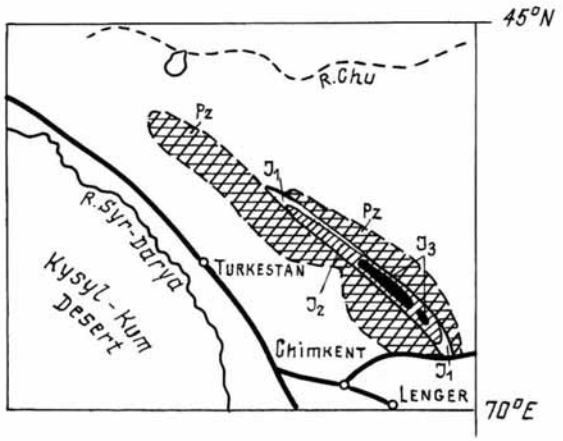
to the east of, the Bolshoy Karatau. The Karatau Range is composed of rocks of almost all geological ages, beginning with the Lower Proterozoic. Jurassic deposits form a narrow belt between the Maly Karatau and the southern and central parts of the Bolshoy Karatau (text-fig. 1). This belt, 2–8 km wide, stretches over 200 km from

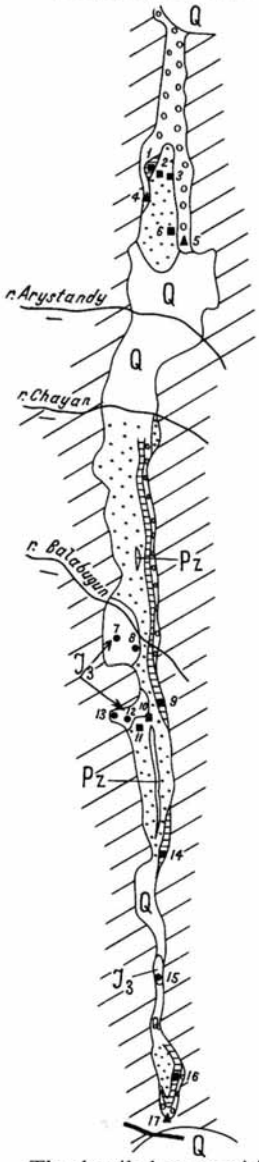


TEXT-FIG. 1. Sketch of southern Kazakhstan to show location of Jurassic deposits (J_1, J_2, J_3) between Palaeozoic rocks (Pz). Thick black lines indicate railways.

the Chokpak pass in the south-east to the valley of the Bala Turlan river in the north-west. The locations of the Jurassic floras of the Karatau Range are given in text-fig. 2.

Jurassic deposits in the Karatau Range were discovered in the second half of the nineteenth century. The first map of Lower and Middle Jurassic outcrops was compiled in 1904 by Veber and Bronnikov. In 1921 the engineer Aniskovich found, near the village of Galkino (now Uspenskoie), outcrops of thin foliated shales with rich remains of the Upper Jurassic fauna and flora. From then on, some interesting localities (Chugurchak, Karabastau and Aulie) were found near the village of Mikhailovka; these contain well-preserved Upper Jurassic plants, insects, fish, and flying reptiles.

The subdivision of these Jurassic deposits has been studied by various geologists and palaeontologists. It is not an easy task, as the Jurassic outcrops are separated and are all continental deposits, containing only plants, fish, and insects. The most complete stratigraphic summary of the Karatau Range was published by Gekker (1948) and Buvalkin (1960; Geology of the U.S.S.R., 1971). In 1971 Sakulina published a paper on the stratigraphy of the upper part of the Karatau Jurassic section. Study of the Jurassic of the Karatau Range continues; new boreholes have been drilled and samples have been collected for a spore-pollen analysis. Sakulina and geologists of the South Kazakhstan Geological Survey are working on the stratigraphic subdivision of the Karatau Jurassic. Sakulina prepared a preliminary new



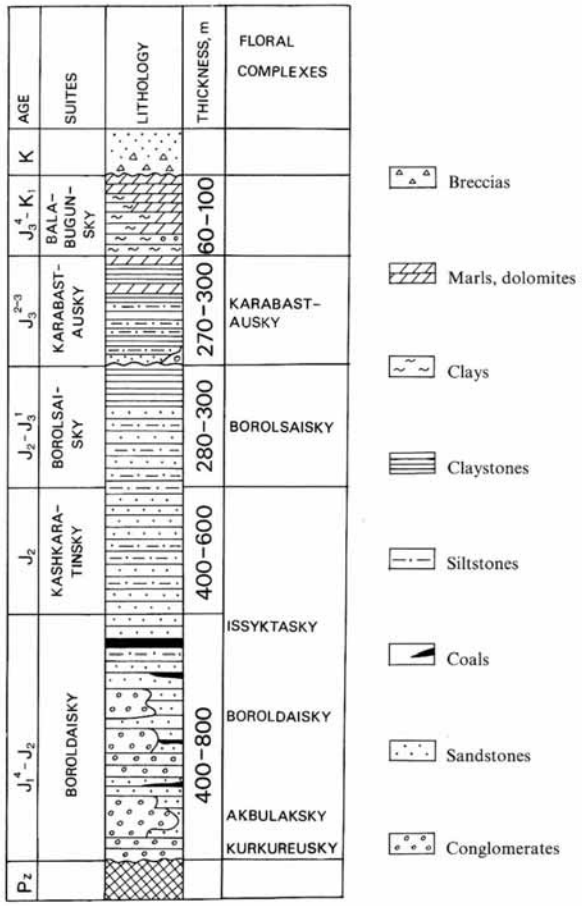
TEXT-FIG. 2. Map of Jurassic deposits indicated in text-fig. 1. Numbered localities containing Early Jurassic floras are indicated by triangles, those containing Middle Jurassic floras are indicated by squares, those containing Late Jurassic floras are indicated by circles. J_3, strata of dolomite, clay limestone, siltstone, sandstone, and combustible shales of the Upper Jurassic Borolsaisky and Karabastausky suites. Pz, Palaeozoic deposits. Q, Quaternary deposits. Dotted areas indicate strata of sandstone, siltstone, and claystone of the Middle Jurassic Boroldaisky and Kashkaratinsky suites. Horizontally lined areas indicate Middle Jurassic coal-bearing measures of the Boroldaisky suite. Open circles indicate Late Lower Jurassic conglomerate strata of the Boroldaisky suite. 1–17, localities containing Jurassic floras, as follows: 1, Taskomyrsaiskoie coal deposit and mining area; 2, Taskomyrsai ravine; 3, Taskomyrsai, exposure 5; 4, Akbulak gully; 5, Kurkureu gully; 6, Issyktas gully; 7, Karabastau; 8, Chugurchak area; 9, Ayak-Sunginskoie coal deposit; 10, Ayak-Sunga river, exposure 24; 11, Kashkarata river; 12, Chokhai area; 13, Aulie area; 14, Boroldaiskoe coal deposit; 15, village of Uspenskoie (Galkino); 16, Chokpak hard coal deposit; 17, Chokpak river (Melnichny area of the Chokpak hard coalfield).

stratigraphic scheme of the Karatau Jurassic, and kindly forwarded it to us (text-fig. 3). This shows the Karatau Jurassic beds resting uncomformably on various Palaeozoic rocks. The lowest member, here called the Boroldaisky suite, extends from the upper part of the Lower Jurassic to the Middle Jurassic. The Kashkaratinsky suite rests conformably on this and passes (also conformably) into the rocks of the overlying Borolsaisky suite. Unconformity has been recorded only between the rocks of the Borolsaisky and overlying Karabastausky suites. The latter three suites correspond to the Chockpaksky, Taskomyrsaisky, and Boroldaisky suites distinguished by Buvalkin (1960).

In these Jurassic suites it is possible to distinguish three floras, each containing two assemblages (text-fig. 3 and Appendix).

Upper Jurassic taphoflora
  Karabastausky assemblage
  Borolsaisky assemblage
Middle Jurassic taphoflora
  Issyktasky assemblage
  Boroldaisky assemblage
Lower Jurassic (late Liassic) taphoflora
  Akbulaksky assemblage
  Kurkureusky assemblage

The detailed composition of each of these six assemblages is given in the Appendix. The main features of these will now be considered in turn.



TEXT-FIG. 3. Stratigraphic scheme of Jurassic deposits of the Karatau Range, compiled by Sakulina. J_1, Lower Jurassic; J_2, Middle Jurassic; J_3, Upper Jurassic; Pz, Palaeozoic.

The Kurkureusky assemblage. This was established by Orlovskaya as occurring in interbeds of sandstone and siltstone within conglomerate strata in the Kurkureu and Betpaksu ravines and by the Chakpak river, in the Melnichny area (text-fig. 2, localities 5 and 17). Notable elements include older types of equisetalean that have persisted since considerably earlier in the Mesozoic (e.g. *Annulariopsis inopinata*),

and abundant specimens of *Neocalamites*. Ferns are strongly represented, particularly species of *Cladophlebis* with large pinnules. Ginkgoalean leaves are common, and cycadophyte leaves are abundant. The presence of the conifer *Storgaardia spectabilis*, known from the Lower Liassic of Greenland, is also noteworthy.

The Akbulaksky assemblage. This was defined by Prinada (in Buvalkin 1958) as occurring in compact grey sandstones in the Akbulak gulley (text-fig. 2, locality 4). Equisetaleans, ferns, and cycadophytes are abundant, but ginkgoaleans, czekanowskialeans, and conifers are now present in a more minor role. *Neocalamites* is still present (though as a different species), but *Annulariopsis* has disappeared. The conifer *Ferganiella* is present, but we nevertheless consider the assemblage to be of late Lower Jurassic rather than Middle Jurassic age. This is because, as a whole, it resembles the Upper Liassic floras of Issyk-Kul Lake (Genkina 1966) and South Fergana (Vakhrameev 1964, 1970). Apart from *Ferganiella*, there is little in the Akbulaksky assemblage to suggest a Middle Jurassic age.

The Boroldaisky assemblage. This assemblage, rich in species, has been recognized in coal deposits of the Boroldaisky, Taskomyrsaisky, Chokpaksky, and Ayak-Sunginsky coalfields (text-fig. 2, localities 1, 2, 9, 14, 16). Romanova (1961) has described some of the species from the Boroldaisky deposits, and some of the species also occur in the Chokpaksky region (Turatanova-Ketova 1936*a*). *Equisetum* is now the dominant arthrophyte, and *Neocalamites* is now found only occasionally. There are many species of the fern *Cladophlebis*, but small-pinnuled forms now predominate. Only one specimen of *Clathropteris* has been found, but *Raphaelia* appears for the first time. Cycadophytes, particularly *Nilssoniopteris*, are common, and several gymnosperm genera are represented by species not found earlier. *Ferganiella* is the commonest conifer, but *Pityophyllum* is also frequent. The assemblage appears to be of early Middle Jurassic age.

The Issyktasky assemblage. This has been recognized in sandstones exposed in the Issyktas gulley of the Taskomyrsaisky coalfield in exposure 5 (text-fig. 2, localities 3 and 6). It also replaces the Boroldaisky assemblage higher in those sections. The Issyktasky assemblage is rather poor in species, but contains abundant specimens of *Phoenicopsis*, *Pityophyllum*, and *Pagiophyllum setosum*, and an increasing diversity of *Nilssonia*. The ferns *Cladophlebis* and *Coniopteris* are, however, rarer. The assemblage appears to be of early Middle Jurassic age, though slightly younger than the Boroldaisky assemblage.

Higher in the Middle Jurassic section lies a Kashkaratinsky suite (not shown in Appendix), exposed in the valley of the Kashkaraty river (text-fig. 2, locality 11). This contains fragments of a typically Middle Jurassic assemblage, similar to floras of that age described from South Fergana (Brick 1935; Vakhrameev 1964, 1969; Gomolitsky 1972) and the Embensky region (Baranova and Kirichova 1972).

The Lower Jurassic (Upper Liassic) to Middle Jurassic floras of the Karatau Range resemble those of the Middle Asian province of the Indo-European palaeofloristic area. They include species not known beyond that province (e.g. *Nilssonia serrata*, *Taeniopteris ferganensis*), others known only in that province (*Cladophlebis magnifolia*, *C. suluctensis*, and *C. czopakensis*), and conifers found only in the

Indo-European area (*Storgaardia spectabilis*, *Ferganiella latifolia*, and *F. lanceolata*). But at the same time, the Karatau floras of this age differ from the southern floras of the Middle Asian province in showing fewer typically southern elements. Neither the Matoniaceae nor the Marattiaceae have been found, and only one species of the Dipteridaceae (*Clathropteris obovata*). The cycadophytes are not varied at specific or generic level, and the southern genera *Ptilophyllum*, *Otozamites*, and *Zamites* have not yet appeared. The Ginkgoales and Czekanowskiales are, however, rich and varied.

Sixtel (1954) and Vakhrameev (1964, 1970) observed differences in the composition of floras within the Middle Asian province of the Indo-European area—mainly that the number of species of cycadophytes diminished while moving northwards, with a simultaneous increase of Ginkgoales and Czekanowskiales. These features are shown by the Lower–Middle Jurassic floras of the Karatau Range located in the northern part of the Middle Asian province (northern subprovince), the Lower–Middle Jurassic floras of the intermontane depression of North Kirghizia, and of the basin of the Issyk-Kul Lake, Angren, Kok-Yangak. The differences between the two floras are probably due to the fact that the floras in the northern subprovince were isolated by mountains from the warm southern seas and lived in a colder and more continental climate.

The Borolsaisky assemblage. This is the earlier of the two Upper Jurassic floras of the Karatau. It was collected in the vicinity of Chokhai (text-fig. 2, locality 12) in deposits of the Borolsaisky suite represented by claystones, siltstones, and combustible shales. These contain small fragments of leaves and shoots, with abundant plant detritus. The specimens are poorly preserved, cuticles are rarely present, and all the plants show signs of having been transported. The Appendix shows the composition of the flora according to the data of Turutanova-Ketova (1950, 1963; Problems of paleontology, 1963), Orlovskaya (1968, 1971), and on the basis of new samples collected by Doludenko. Turutanova-Ketova assigned this flora to the Middle Jurassic. However, because there are no equisetaleans and very few ferns, but a large number of conifers and cycadophytes, we consider that the flora is of Late Jurassic age.

The Karabastausky assemblage. This, the second Upper Jurassic flora, was collected in deposits of the Karabastausky suite of the Aulie area (text-fig. 2, locality 13). Specimens have been found near Chugurchak, Karabastau, and near the village of Uspenskoie (formerly Galkino) (text-fig. 2, localities 7, 8, 15). The Karabastausky suite is represented by thinly laminated carbonate rocks which contain an exceptionally rich and diverse flora and fauna. These sediments were deposited in the Upper Jurassic lake studied by Gekker (1948). Large, very well-preserved leaves of bennettitaleans and cycads, over 50 cm long, and large branches of conifers are common. The phytolema of many leaves is preserved, especially those of the conifers *Brachyphyllum* and *Pagiophyllum*, and we were able to extract spores from sporangia of *Stachypteris* and *Coniopteris*.

The Karabastausky flora is typical of the Upper Jurassic, having extremely few equisetaleans and ferns, but these include *Stachypteris*. It abounds in Bennettitales, especially *Ptilophyllum* and *Otozamites*, while cycads and the conifers *Brachyphyllum*

and *Pagiophyllum* are prevalent. The Karabastausky flora is most similar in aspect to the Upper Jurassic floras of Georgia (Doludenko and Svanidze 1968, 1969), the Gissarian Range (Luchnikov 1972), and France (Saporta 1873, 1875, 1884, 1891; Lemoigne and Thierry 1968; Barale 1970; Borale, Cariou and Radureau 1974).

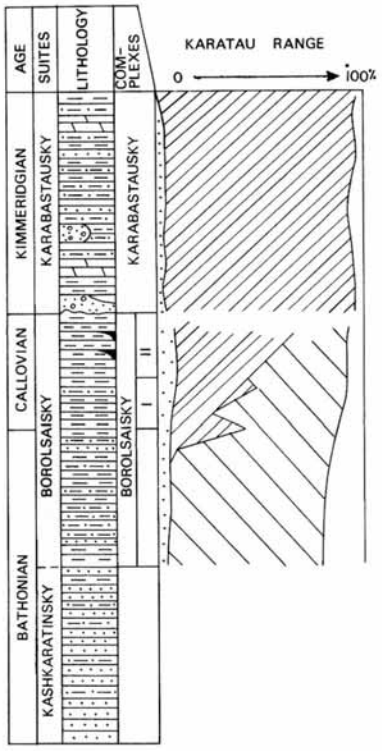
Miospores of the Upper Jurassic floras and their ages

The study of spore-pollen spectra from Jurassic deposits of the Karatau carried out during recent years by Vakhrameev and Yaroshenko (1958), Murakhovskaya (1968), and to a greater extent Sakulina (1968, 1971) enable us to determine the ages of the above two Upper Jurassic floras more precisely.

The spore-pollen assemblages from the upper part of the Borolsaisky suite in the vicinity of Chokhai have been described by Sakulina (1968, 1971), who has recognized two subassemblages of miospores (text-fig. 4). The earlier subassemblage is characterized by the prevalence of disaccate pollen *Disaccites*, and the presence of a large amount of *Classopollis* pollen. The amount of *Classopollis* is negligible at first (0–2%), then gradually increases to 10–14%, jumps to 50%, and finally decreases to 10–20%. There are few species of *Classopollis* (mostly *C. classoides* and *C. minor*). Spores make up only 5–8% of this assemblage, rarely as much as 15%. The later subassemblage is characterized by an increased amount of *Classopollis* (38–58%) and a decreased amount of disaccate pollen; not more than 8% is made up of spores.

Sakulina (1971) surveyed the spore-pollen assemblages from the Bathonian–Tithonian deposits of Mangyshlak, western Uzbekistan, and the Karatau. She shows that those assemblages from the Early and Middle Callovian contain a lower content of *Classopollis* pollen (up to 50%, less frequently 70%) than those from the Upper Callovian–Tithonian. These comparative studies of miospore assemblages help in estimating the age of the Borolsaisky and Karabastausky assemblages. They indicate that the two miospore subassemblages from the Borolsaisky suite are probably of Early to Middle Callovian age.

Classopollis pollen is produced by members of the conifer family Cheirolepidiaceae, as



TEXT-FIG. 4. Diagram showing the distribution of *Classopollis* and of certain other miospores (after Sakulina 1971). *Right*, composition of pollen assemblages; dotted area represents percentage made up of spores, fine hatching indicates percentage made up of *Classopollis* pollen, coarse hatching indicates percentage made up of *Disaccites* pollen. Conglomerates, sandstones, etc., shown as in text-fig. 3.

are the shoots known as *Brachyphyllum* and *Pagiophyllum*. Vakhrameev (1970) has shown that the relative abundance of these elements of the floras can be used to define three climatic belts of latitude within the U.S.S.R. and adjoining regions, during the Bathonian, Late Jurassic, and Valanginian. The most southerly of these belts covers Moldavia, the Dnieper–Donets depression, Donets Basin, Crimea, Caucasus, Middle Asia, and Kazakhstan (including the Karatau region). In these regions there was, during the Bathonian, a notable decrease in the amount of *Classopollis* pollen (often of 15% and sometimes of 40%). In the Callovian, especially in the late Callovian, there was an increase in *Classopollis* to 60–75%, with a decrease in the percentage of spores of ferns and pine-like pollen. In the Oxfordian and Tithonian the amount of *Classopollis* pollen reaches 80–85% and sometimes even 95–100%.

Comparison of the composition of these two miospore subassemblages with those surveyed by Sakulina (1971), mentioned above, shows that they are characteristic of those from Lower and Middle Callovian times.

The spore-pollen assemblage of the Karabastausky suite has been studied by Murakhovskaya (1968) and Sakulina (1968, 1971). *Classopollis* pollen forms 95–100% of the assemblage throughout. The species of *Classopollis* are *C. classoides*, *C. pfluggii*, *C. intunensis*, *C. minor*, and *C. gyroflexus*. The amount of disaccate pollen *Disaccites* decreases to 2%. In the Karabastausky suite there occur *Perinopollenites*, *Foveoinaperturites*, *Ginkgocycadophytus*, *Inaperturopollenites*, *Araucariacites*, and *Caytonipollenites*. The spore *Cyathidites australis* predominates, while the following are sporadic: *Gleicheniidites*, *Sphagnumsporites*, *Lygodiumsporites*, *Concavisporites*, *Apiculatisporites*, *Tripartina variabilis*, *Laevigatosporites ovatus*, and *Ciborium junctum*.

Sakulina (1971) considers that assemblages similar to those found in the Karabastausky suite have been found in sediments of a wide range of ages, from Late Callovian to Kimmeridgian. Since no distinct series of miospore assemblages for this period of time have yet been recognized, this approach does not help in providing a more precise age for the Karabastausky deposits or flora. It is clearly, of course, later than the Borolsaisky deposits and assemblages, but the length of any gap in time between the two is unknown.

In summary, the plant macro-fossils and miospores both suggest a Late Jurassic age for the Borolsaisky and Karabastausky suites, while the miospores indicate, more precisely, that the Borolsaisky belongs to the Lower–Middle Callovian.

GENERAL DISCUSSION

A thorough study of floras growing in the restricted Karatau area during the Jurassic enables us to follow how the flora changed with age, climate, and the palaeogeographical environment. An analysis of the generic composition of the Jurassic flora of the Karatau suggests the following picture (Table 1).

The genera common in Lower, Middle, and Upper Jurassic deposits of the Karatau are as follows: *Equisetum*; ferns: *Clathropteris*, *Coniopteris*, *Cladophlebis*; cycadophytes: *Anomozamites*, *Pterophyllum*, *Williamsonia*, *Williamsoniella*, *Nilssonia*, *Pseudoctenis*, *Taeniopteris*; Ginkgoales and Czekanowskiales: *Ginkgoites*, *Sphenobaiera*, *Eretmophyllum*, *Czekanowskia*, *Phoenicopsis*; conifers: *Storgaardia*, *Podoza-*

TABLE 1. The generic composition of the Lower, Middle, and Upper Jurassic floras of the Karatau region. Columns Ku, Ak, Bd, Is, Bs, and Ka represent the Kurkureusky, Akbulaksky, Boroldaisky, Issyktasky, Borolsaisky, and Karabastausky floras, respectively. The numbers indicate the number of species of each genus in each flora.

		Ku	Ak	Bd	Is	Bs	Ka
ARTHROPSIDA	*Annulariopsis*	1					
	Neocalamites	1	2	1	1		
	Equisetum	1	1	2	2		1
FILICES	*Coniopteris*	2	2	3	1		3
	Sphenopteris						2
	Cladophlebis	6	6	10	3	1	1
	Clathropteris	1	1	1			1
	Raphaelia			2			
	Hausmannia						1
	Stachypteris						1
CAYTONIALES	*Sagenopteris*					1	1
BENETTITALES	*Nilssoniopteris*	1		2			
	Williamsoniella	1				2	1
	Anomozamites		6	2		1	
	Pterophyllum		2			1	1
	Williamsonia			1		1	
	Otozamites					1	5
	Ptilophyllum						1
	Zamiophyllum						1
	Zamites						1
	Sphenozamites						1
	Weltrichia						1
CYCADALES	*Nilssonia*	1	1	2	3	1	3
and unplaced	*Pseudoctenis*	2			1	1	
CYCADOPHYTA	*Paracycas*						1
	Taeniopteris	1	3	2	1		1
	Cycadites						2
GINKGOALES	*Ginkgoites*	2	2	2	1		1
	Baiera	1					1
	Sphenobaiera	1		1	1		2
	Pseudotorellia		1		2		
	Eretmophyllum			1			1
CZEKANOWSKIALES	*Czekanowskia*		1	3		1	1
	Phoenicopsis	1		2	2		1
CONIFERALES	*Storgaardia*	1				1	1
	Pityophyllum	2	2	2	1	2	1
	Podozamites		2	1			1
	Ferganiella		1	3			
	Elatocladus			1		1	3
	Pagiophyllum				1	1	5
	Brachyphyllum					1	5
	Araucarites						1

mites, *Pityophyllum*, *Elatocladus*, and *Pagiophyllum*. However, though most of these genera abound in the Lower and Middle Jurassic deposits, by the Upper Jurassic they are usually less numerous or even sporadic. A few genera are more restricted in their appearance in the Lower and Middle Jurassic. *Annulariopsis* is found only in the lower parts of the upper Lower Jurassic. The fern *Raphaelia* occurs only in the Middle Jurassic, and the conifer *Ferganiella* is known only in the upper part of the Lower Jurassic and the lower part of the Middle Jurassic. A number of genera, absent from earlier Karatau deposits, thus appear there in the Upper Jurassic, for the first time, as follows: *Hausmannia*, *Stachypteris*, *Sagenopteris*, *Otozamites*, *Ptilophyllum*, *Zamiophyllum*, *Zamites*, *Sphenozamites*, *Weltrichia*, *Paracycas*, and *Cycadites*, as well as conifers: *Araucarites*, *Brachyphyllum*, and *Pagiophyllum*, only the last being known in the uppermost parts of the Middle Jurassic. Many of these (*Ptilophyllum*, *Otozamites*, *Brachyphyllum*, *Pagiophyllum*, etc.) migrated to the Karatau from more southern regions and rapidly became predominant there.

The Karatau flora underwent significant changes during the 30–35 million years of its existence, these being especially pronounced in the Late Jurassic.

The early Middle Jurassic flora of the Karatau with taphocoenoses of the usual Kazakhstan Jurassic composition, consists of equisetaleans, ferns (*Clathropteris*, *Cladophlebis*, and *Coniopteris*), typical Jurassic Ginkgoales and Czekanowskiales, relatively uniform cycadophytes (*Anomozamites*, *Nilssoniopteris*, *Nilssonia*, *Pseudoctenis*, and *Taeniopteris*), and conifers; along with the widespread *Pityophyllum* and *Podozamites*, the broad-leaved *Ferganiella* is numerous. This flora gives way to a new type of flora resembling the Upper Jurassic floras of France and Georgia, characterized by the predominance of Bennettitales (Ptilophyllum, Otozamites) and conifers of the *Brachyphyllum–Pagiophyllum* type, a small number of ferns and Ginkgoales, and only occasional equisetaleans.

The floral changes of the Karatau region during the Jurassic can be related to alterations in the palaeogeographical conditions and climate. In Early to Middle Jurassic times, the Karatau deposits appear to have accumulated in an alluvial plain with numerous rivers with oxbows. We picture the climate as warm and humid, permitting the vigorous growth of a rich vegetation that covered the banks of the rivers and, no doubt, the higher ground also. Huge masses of dead plants, later to form coal, accumulated in the swamps.

In the Late Jurassic a very large lake formed in place of the alluvial plain. This was called Lake Karatausky by Gekker (1948), but Buvalkin (1968) named it Lake Karabastausky. It was a mountain lake with rocky banks, its water containing great amounts of calcium and magnesium salts. The banks of the lake and of the rivers flowing into it were covered by rather rich vegetation. When judged by the composition and structure of the plants, the Karatau climate of this time was dry and hot. Lake Karatausky was in the belt of arid climate that appeared in the Late Jurassic within the Indo-European palaeofloristic area, stretching from the western boundary of Spain and France via South Europe, the Caucasus, Kazakhstan, and the Middle Asian province to Central China. Such a climatic change from a humid Early and Middle Jurassic and an arid Late Jurassic was suggested by Strakhov (1960), and would certainly have affected the composition of the Karatau flora.

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APPENDIX

Comparison of the specific composition of Early, Middle, and Late Jurassic floras of the Karatau (from the data of Brick (1925*a–c*), Orlovskaya (1968, 1971), Prinada (*in* Buvalkin, 1958), Romanova (1961), Turutanova-Ketova (1929, 1930, 1936*a*, *b*, 1950, 1963), The principles of palaeontology (1963), Gekker (1948), and the authors).

The detailed composition of each flora is given in turn. Each taxon is listed under the *first* flora in which it occurs. If any taxon also occurs in a later flora, this is shown as a number after its name, as follows: 1, Akbulaksky assemblage; 2, Boroldaisky assemblage; 3, Issyktasky assemblage; 4, Borolsaisky assemblage; 5, Karabastausky assemblage.

Lower Jurassic Kurkureusky flora:

Annulariopsis inopinata, *Neocalamites issykkulensis*, *Equisetum* ex gr. *gracilis*, *Clathropteris obovata* (1), *Coniopteris zindanensis*, *Coniopteris* sp. (1–3), *Cladophlebis denticulata* (1–3), *C. nebbensis* (1–3), *C. whitbiensis* var. punctata (1, 2), *C. czokpakensis*, *C. haiburnensis* (1–3), *C. magnifolia* (1, 2), *Nilssoniopteris karataviensis*, *Williamsoniella vachrameevii*, *Nilssonia acuminata* (1–3), *Pseudoctenis locusta*, *Taeniopteris* sp. A, *Ginkgoites* ex gr. *sibiricus* (2, 3, 5), *Baiera* cf. *gracilis*, *Sphenobaiera* sp., *Phoenicopsis* ex gr. *angustifolia* (2, 3, 5), *Storgaardia spectabilis*, *Pityophyllum angustifolium* (1, 2, 4), *P.* ex gr. *nordenskioldii* (1–4), *Pityocladus kobukensis* (1, 3), *Stenorhachis dubius*, *Carpolithes heeri*.

Lower Jurassic Akbulaksky flora:

Neocalamites hoerensis, *Neocalamites* sp. (2, 3), *Equisetum laterale* (2, 3, 5), *Coniopteris* ex gr. *hymenophylloides* (2, 5), *Cladophlebis suluktensis* (2), *Anomozamites lindleyanus*, *A. dentatus*, *A. elegans*, *A.* ex gr. *inconstans*, *A.* cf. *lockyi*, *Anomozamites* sp. (4), *Pterophyllum* cf. *tietzei*, *Pterophyllum* sp. (4, 5), *Taeniopteris ferganensis* (2), *T.* ex gr. *amurensis*, *Ginkgoites* sp. A, *Pseudotorellia* sp. (2, 3), *Czekanowskia rigida* (2), *Podozamites lanceolatus* (2, 5), *P.* cf. *latifolius*, *Ferganiella ovalis* (2).

Middle Jurassic Boroldaisky flora:

Marchantites baicalensis, *Lycopodites trichiatus*, *Equisetum hallei*, *Clathropteris* sp. (5), *Cladophlebis bidentata*, *C. argutula*, *C. kamenkensis*, *C.* aff. *magnifica*, *Raphaelia diamensis* forma *spinosa*, *R. dentata*, *Nilssoniopteris* aff. *vittata*, *N. boroldaica*, *Anomozamites kornilovae*, *Williamsonia haydenii*, *Nilssonia* sp. (3, 4), *Taeniopteris ensis*, *Ginkgoites* sp. B, *Eretmophyllum boroldaica*, *Sphenobaiera longifolia*, *Phoenicopsis* ex gr. *rarinervis*, *Czekanowskia ketovae*, *Czekanowskia* sp. (4), *Ixostrobus heeri* (3), *Elatocladus conferta*, *Ferganiella lanceolata*, *F. latifolia*.

Middle Jurassic Issyktasky flora:

Thallites sp., *Equisetum* cf. *beanii*, *Equisetum* sp., *Nilssonia serrata*, *Taeniopteris* sp. (5), *Sphenobaiera* sp. B, *Pseudotorellia ephela*, *Phoenicopsis* ex gr. *speciosa*, *Pagiophyllum setosum* (4).

Upper Jurassic Borolsaisky flora:

Cladophlebis sp. (5), *Sagenopteris phillipsii* (5), *Williamsoniella karataviensis* (5), *W. czochaiensis*, *Williamsoniella* sp., *Williamsonia* sp., *Otozamites* sp., *Brachyphyllum* sp., *Elatocladus ketovae*, *Elatocladus* sp., *Taxocladus*? sp., *Storgaardia* sp,, *Pityspermum crassialigerum*, *P. cuneatum*, *P. falciforme* (5), *P. gracile* (5), *P. karataviense* (5), *P. lacum* (5), *P. lundgrenii* (5), *P. maakiana* (5), *P. nansenii* (5), *P. obliquum* (5), *P. parallelimarginale*, *P. pinisimulans*, *Pityostrobus* sp. (5), *Machairostrobus kazachstanicus*, *Masculostrobus* sp., *Carpolithes heeri*, *C. karatavicus*, *C. cinctus*, *Platylepidium oblanceolatum* (5), *P. leve* (5), *P. minus*, *Samaropsis rotundata*, *S. problematica*, *S. kazachstanica*, *Stenomiscus magnus*.

Upper Jurassic Karabastausky flora:

Marchantites sp., *Stachypteris turkestanica*, *Coniopteris angustiloba*, *C. murrayana*, *Sphenopteris modesta*, *S.* cf. *moissenetii*, *Hausmannia* sp., *Weltrichia auliensis*, *Ptilophyllum caucasicum*, *Otozamites turkestanicus*, *O. hislopii*, *O. latior*, *O. giganteus*, *O.* cf. *beanii*, *Sphenozamites sphenozamioides*, *Zamiophyllum buchianum*, *Zamites*? sp., *Cycadolepis* sp., *Paracycas harrisii*, *Nilssonia* aff. *obtusa*, *N.* ex gr. *orientalis*, *Cycadites dubius*,

C. saportae, *Baiera colchica*, *Sphenobaiera kazachstanica*, *S. spectabilis*, *Eretmophyllum magnum*, *Czekanowskia auliensis*, *Desmiophyllum* sp., *Araucarites vassilevskae*, *Brachyphyllum mamillare*, *B. expansum*, *B. expansum* var. *gracilis*, *B. expansum* var. *falcata*, *B. mamillareforme*, *B. gracile*, *B. brickae*, *Pagiophyllum peregrinum*, *P. papillatum*, *P. ketovae*, *P.* cf. *burmense*, *P. falcatum*, *Pagiophyllum* sp., *Elatocladus jabalpurensis*, *E. minutus*, *E. subzamioides*, *Storgaardia kazachstanica*, *Podozamites angustifolius*, *Pityophyllum* sp., *Pityospermum cedriformis*, *Conites* sp., *Carpolithes karatavicus*, *Problematospermum ovale*, *P. elongatum*.