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PERMIAN-TRIASSIC BOUNDARY IN THE KAP STOSCH AREA, EAST GREENLAND

BY

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APPENDIX

Conodonts from the Permian-Triassic boundary beds at Kap Stosch, East Greenland

BY

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WITH 7 FIGURES, 1 TABLE AND 16 PLATES

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Abstract

Study of several Permian-Triassic sections in the Kap Stosch region of East Greenland (74°04′ N. lat., 21°42.5′ W. long.) in the summer of 1967 has provided a number of new observations. The Permian-Triassic sequence southwest of Kap Stosch consists of homogenous shale, silty shale, and siltstone. None of the rock units are highly indurated. Solifluction has so badly disturbed all outcrops that it is all but impossible to measure meaningful stratigraphic sections. The lowest Triassic beds in these regions do contain thin (1–5 cm) hard bands consisting of coquinas of ammonoids (*Glyptophiceras* and *Otoceras*) and containing fragments of bryozoans, productids, and other fossils of Permian affinities.

Southeast of Kap Stosch, especially between Rivers 6 and 14, the lowest Triassic strata encompassing the *Glyptophiceras* Zone are about 200 meters thick. They are predominantly arkosic sandstone and conglomerate. A number of coarse sandstone and conglomerate beds yielded fragmentary as well as entire specimens of productid brachiopods, fragments of bryozoans, crinoid stems, and other Permian fossils, occurring to a distance of as much as 100 m above the base of the Triassic sequence.

Thickness, sedimentary structures, and composition of the strata containing these mixed associations clearly indicate very rapid rates of deposition, leading us to the conclusion that during earliest Triassic time the "Permian" elements of the fauna almost certainly did not actually live in places where they are found. The underlying Permian formations are of diverse facies, including richly fossiliferous biohermal banks which are close to the study area. Some of these banks weather easily, yielding almost perfectly preserved fossils when freed of matrix. We consider it most probable that the majority of fossils were washed out of soft rocks and were badly broken during transportation. Some of the Permian fossils in the lowest Triassic formations were transported in clay balls that, once coming to rest, dissolved, leaving well preserved fossils that were then transported very little, and were rapidly buried in the coarse sediment.

We conclude that the Permian-Triassic sequence in the area encompasses a break equivalent to at least the Changhsingian Stage.

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INTRODUCTION AND ACKNOWLEDGEMENTS

In the geological literature on East Greenland, there had been persistent reports, at least since 1930, of co-occurrences in the same beds of Paleozoic-type fossils, especially brachiopods and bryozoans, with *Ophiceras* and other ammonoids, generally regarded as indicative of earliest Triassic age. But these occurrences had never been described in detail nor had their exact stratigraphic relationships been made known. It had long been our plan to do this.

Unfortunately, the east coast of Greenland is one of the most inaccessible areas in the world and it was not until 1967 that a fortunate coincidence of circumstances made it possible for us to carry out our plan. The Danish paleontologists Eigil Nielsen, Svend Erik Bendix-Almgreen, and Tove Birkelund and her assistant, Lone Malmros, laid plans for a visit to Kap Stosch, mainly to study the Triassic rocks of the area and we were invited to join them. At our suggestion Professor Rudolf Trümpy, Zurich, was also invited to be a member of our party. In addition, we ourselves had a field assistant each, Victoria Kohler and Pat Lohmann, so that our party numbered a total of nine persons. Our activities were briefly reported by Birkelund (1968).

We are greatly indebted to our Danish companions for helping us to arrange transportation to Greenland by the icebreaker Nella Dan, and from Greenland to Reykjavik by Danish Army flying boat. We also wish to express appreciation to them for help and stimulating discussions in the field, and we thank especially our assistants for efficient services rendered in laboratories after our return from Greenland. G. D. Stanley assisted Teichert in the final stages of manuscript preparation in the winter of 1974–1975. Finally, we are grateful to the crew of the Danish Station Daneborg on Wollaston Forland who on several occasions provided invaluable logistical support.

We are greatly indebted to W. C. Sweet who processed many of our samples for conodonts. His identifications have been incorporated in our text and the more detailed account is added as an Appendix to this paper.

Our work in East Greenland and some of the follow-up work was supported by National Science Foundation grant GA–996. G. D. Stanley was supported by the Wallace E. Pratt research fund in the Paleontological Institute, University of Kansas.

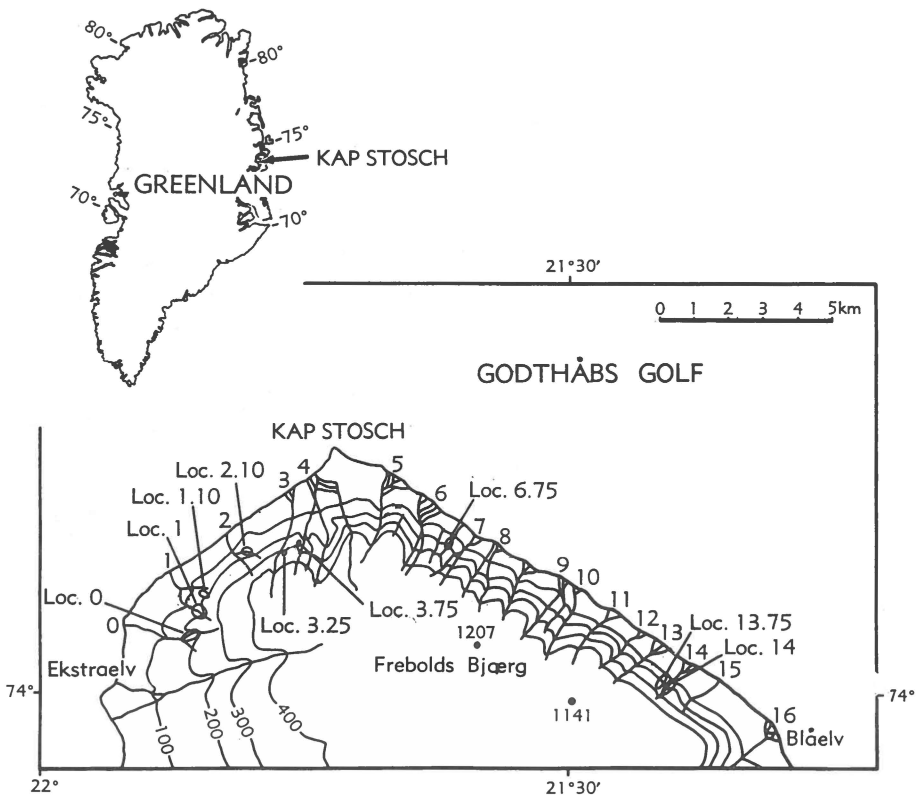

Fig. 1. Sketch map of Kap Stosch area, and map of Greenland showing location of Kap Stosch.

PRESENT WORK

During our stay of approximately four weeks in the Kap Stosch area (74°04′ N. lat., 21°42.5′ W. long.; Figs. 1,2) in July and August, 1967, we worked out of two camp sites. Our first camp was situated at the coast on the southeast side of River 3 and from there we worked sections as far as River Zero to the southwest and River 8 to the southeast. About halfway through our stay we shifted camp to the coast at River 10 and worked over the sections between Rivers 8 and 14. All in all, our investigations covered about 20 km of coastline. Although coastal cliffs were at that time of the year practically free from snow, the quality of outcrops is generally poor, because they are disturbed by soil flow, or solifluction. This is particularly damaging to the Permian portion of many stratigraphic sections because of prevalence of shale and siltstone. In addition, there is also much soil creep in those parts of the Triassic sections where fine-grained and looosely cemented sandstone occurs.

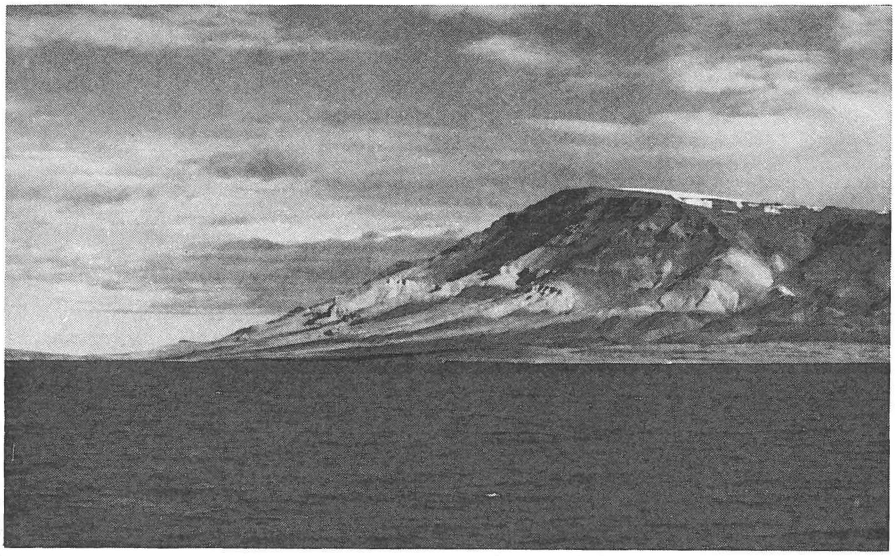

Fig. 2. Coast southeast of Kap Stosch with Frebolds Bjerg.

The numbering system for the many creeks and rivers that drain the highlands south and southeast of Kap Stosch was introduced by Koch (1931) and is shown on his Plate 1. Throughout the text of his paper Koch referred to these rivers by the numbers he gave them, but did not explain the system as such as he made no attempt to identify the locations of older names such as Foldvik Creek and Wordie Creek that he had used in 1929.

The numbering system for these rivers is convenient and most are easy to identify in the field. Koch named only the larger rivers, essentially those with prograding deltas. This procedure left many smaller rivers unidentified, but makes it easy to indicate localities between the larger rivers by assigning to them decimal fractional numbers. Thus, a locality situated about one-quarter of the way between Rivers 8 and 9 is called 8.25, and one about three-quarters of the way between Rivers 13 and 14 is called 13.75 (Fig. 1). For reasons of uniformity, we refer to all our investigative sites as "localities".

A preliminary report of our findings was presented at the symposium on the Permian and Triassic Systems and their mutual boundary, held in Calgary, Alberta, in August, 1971 (Teichert & Kummel, 1971, 1972).

HISTORY OF STRATIGRAPHIC CONCEPTS

Discovery Stage

In order to understand the geological conditions in the Kap Stosch area and the origin and development of our project, it is necessary to consider briefly the history of some of the ideas on the stratigraphy of this area.

The history of geological investigations in the Kap Stosch area begins with a visit by a British expedition led by J. M. Wordie in the summer of 1926. The Wordie party discovered "a belt of white and red sandstones and shales with characteristic Lower Triassic ammonites" (Wordie, 1927, p. 253). These fossils were studied in quick succession by L. F. Spath (1927) who recognized presence of the genera *Ophiceras*, *Koninckites*, *Vishnuites*, and *Proptychites*, an assemblage indicative of various parts of the Scythian Stage. Wordie made no mention of Paleozoic rocks in this area.

Discovery of Paleozoic strata in the Kap Stosch area had to wait until Lauge Koch's visit on a sledge trip in the spring of 1927. He first reported on his finds in two short papers (Koch, 1928a, b) in which he mentioned a white limestone with an Early Carboniferous fauna and, in higher stratigraphic position, the "well-known *Productus* fauna of Late Carboniferous and Permo-Carboniferous age".

In two important publications in 1929 Koch described the late Paleozoic as well as the Triassic sequence from the Kap Stosch area, as it was then known to him (Koch, 1929a, b). At the same time he made an attempt to name lithological units as formations in the manner of the American tradition with which he had then just become acquainted. Because of later confusion surrounding some of these formation names, they must be considered here in some detail.

Foldvik Creek Formation

In the Kap Stosch area, Koch named and described two formations which he assigned to the upper Paleozoic: Foldvik Creek Formation and Cape Stosch Formation.

The Foldvik Creek formation was established by Koch (1929a, p. 94–95, 1929b, p. 244) for a rock sequence in the general neighborhood of Kap Stosch, where it overlies conglomerates of supposedly Devonian age. The section as described by Koch is as follows (somewhat condensed from the original; numbering introduced herein):

Koch's *1929 section of Foldvik Creek Formation*

		Thickness (meters)
3.	Gray shale and brown sandstone	110
2.	Black shale and brown limestone, containing *Posidonomya* and fishes	10
1.	Gray sandy shale with bands of red and white gypsum	30
		150

Koch assigned the formation to the lowermost Carboniferous or, possibly, uppermost Devonian. The type locality is given as "Foldvik Creek, about 6 km southeast of Cape Stosch". This name is not to be found on any subsequent or current topographic or geologic maps. It was during the 1929 expedition that the numbering system for the rivers in the Kap Stosch area was introduced and earlier names, given by Koch in 1929, were suppressed. According to Tove Birkelund and S. E. Bendix-Almgreen (oral communication, summer 1967), Koch's original Foldvik Creek is either River 7 or River 8 of later papers (Koch, 1931; Eigil Nielsen, 1935), most probably River 8.

In subsequent years the name Foldvik Creek Formation was used intermittently, sometimes in quotation marks (Kulling, 1930), or not at all. The reason was mostly unfamiliarity of authors with the methodology of lithostratigraphic terminology which Koch had attempted to apply in 1929.

In 1930, Kulling (p. 344) described a section of the Foldvik Creek Formation from a locality "about 2 km southwest of Cape Stosch" (presumably River 2) which is discussed in more detail below in the section on Locality 2.

Rosenkrantz (1930) adopted the name Foldvik Creek Formation and studied this unit in some detail on Clavering Ø (Island) and near Kap Stosch. At a locality "slightly east of Cape Stosch" he distinguished the following subdivisions (condensed from original):

Rosenkrantz's *1930 section of Foldvik Creek Formation*

3. Brachiopod limestone, thin-bedded marly limestone with indeterminable plant remains, brachiopods, gastropods and occasional shark teeth and spines.
2. Shale and mud series, containing *Posidonomya*, hook-shaped fossils of cephalopodan affinities, and others.
1. Gypsiferous series, mostly gypsum and dolomite.

ROSENKRANTZ estimated the total thickness of the formation not to exceed 200 meters. He believed the formation to be Late Carboniferous in age, because he found it to rest on a conglomerate containing supposedly middle Carboniferous plant fossils.

KOCH (1931, p. 21–28) summarized KULLING'S (1930) and ROSENKRANTZ'S (1930) observations and mentioned that he had called these beds Foldvik Creek Formation in 1929, but discontinued use of this name. He also described in greater detail the section at River 7. This section follows (modified and condensed from original; numbering introduced herein):

KOCH'S *1931 section of Foldvik Creek Formation at River 7*

	Thickness (meters)
7. Shale, reddish	36
6. Shale, sandy, gray, calcareous	10
5. Sandstone, shaly, unfossiliferous	110
4. Clay, with interbedded limestone, in lower part crowded with bryozoans	0.3
3. Limestone, containing fish remains	0.3–0.5
2. *Posidonomya* shale	23
1. Dolomite and gypsum	0.5–1
	180

Total thickness at this section is about 180 m, or 145 m, if the uppermost unit 7 is excluded. It is possible that this is the type section of the Foldvik Creek Formation as described by KOCH in 1929. The main discrepancy is the great thickness (30 m) stated by KOCH for the basal gypsiferous unit in the 1929 paper, but this may well be a matter of exposure.

The history of investigation of the Foldvik Creek Formation up to about the year 1938 has been described in some detail by MAYNC (1942, p. 12–16), especially with reference to the works of FREBOLD (1931a, b, 1932 and other publications), EIGIL NIELSEN (1935), and ALDINGER (1935). By this time it was realized that the Foldvik Creek Formation, although this name had almost fallen into disuse, was of Late Permian age, rather than Early Permian (FREBOLD) or Late Carboniferous (ROSENKRANTZ) as had been suggested before.

MAYNC (1942) made substantial contributions to the knowledge of the Foldvik Creek Formation on eastern Clavering Ø and Wollaston

Forland. In the Kap Stosch area he measured only one section, at River 14, as follows (condensed from the original; numbering introduced herein):

MAYNC's *1942 Permian section at River 14*

	Thickness (meters)
6. *Martinia* limestone, rather flaggy	4
5. *Productus* limestone, greenish, gray, and reddish, rich in Bryozoa	0.8
4. *Martinia* limestone, with many marly zones, with reddish, hard limestone bed at 15 m	25
3. *Posidonomya* shale, black, brittle, bituminous, calcareous shale with numerous limestone beds	10
2. Dolomite, calcareous, partly oolitic	7
1. Conglomerate	100
	147

It should be noted that there are considerable differences in lithology and thickness between this section and the type section, situated about 6–7 km to the northwest, particularly in the lower two-thirds of the sections.

As far as the stratigraphy of the Foldvik Creek Formation is concerned, no significant contributions have been made since MAYNC's paper of 1942, although some important additions to the knowledge of its fossils were made known. MILLER & FURNISH (1940) had shown that the formation contains *Cyclolobus* an occurrence which places it very high in the Upper Permian. NEWELL (1955) described the pelecypod fauna of the Foldvik Creek Formation and demonstrated, among other things, that the name-giving genus of the much discussed *Posidonomya* shale was *Posidonia*, not *Posidonomya*.

TROELSEN (1956) gave a brief description of the Foldvik Creek Formation and its history, and more recently the name has been resurrected by some American authors (DUNBAR, 1960, p. 1778; NASSICHUK *et al.*, 1965, p. 3; FURNISH, 1966, p. 269) and by TRÜMPY (*in* CALLOMON, DONOVAN, & TRÜMPY, 1972, p. 7), although he regarded the term as "not too satisfactory".

KEMPTER (1961, p. 74) realized that the Permian complex of the Clavering Ø-Kap Stosch area consisted of several "formations" in sense of the American usage, but made no attempts to name them.

BIRKELUND *et al.* (1974) used the name Foldvik Creek Formation for the entire Upper Permian sequence and stated that it consisted of eight members which, however, were named only informally. No type locality was indicated for the formation nor any of its members.

Productus limestone

Since most of the Permian fossils in the basal Triassic conglomerates in the Kap Stosch area have most probably been washed out of the unit long known as "*Productus* limestone" as well as overlying shale units, a word about the "*Productus* limestone" and related units is in order.

The term "*Productus* limestone" was presumably first used for a rock unit in East Greenland by Kulling (1930, p. 344) for a 10 meter thick limestone unit in a section "2 kilometers southwest of the Norwegian house, southwest of Cape Stosch". He described the unit as rich in corals, bryozoans, brachiopods, and crinoids.

The name was later widely and loosely used, especially when it was discovered that rocks in similar facies occur at various stratigraphic levels in the late Paleozoic sequence of East Greenland (see Frebold, 1932, p. 29).

The term "*Productus* limestone" points up the inadvisability of naming lithostratigraphic units after fossils, because, as is true for its namesake in the Salt Range in Pakistan, the genus *Productus*, as now interpreted, is not among its fauna (Dunbar, 1955).

According to Maync (1942) and Dunbar (1955) the "*Productus* limestone" occurs normally as a bed or beds, not more than 4 or 5 m thick, either in the midst of the "*Posidonia* shale" or the "Martinia-kalk" or "*Martinia* shale", or below or above these units. Dunbar (1955, p. 40) called this unit a lithotope, a term which he also applied to the other facies units of the East Greenland Permian. Other such lithotopes are massive dolomite, gypsum, *Posidonia* (originally *Posidonomya*) shale, Red Series, and others.

Cape Stosch Formation

The Cape Stosch Formation was named and described by Koch (1929a, p. 112; 1929b, p. 247) as consisting of coarse conglomerate and sandstone, about 300 m thick, which contain boulders suggesting a variety of origins. He regarded as most characteristic the conspicuous boulders of white, oolitic limestone crowded with fossils, mostly brachiopods and bivalves. Koch (1929a, p. 116–117) listed a number of species, identified by Rosenkrantz (1929), that suggested a Late Permian age and close faunal relationships with the Zechstein of England and Germany. On this basis, Koch assigned a Late Permian age to the Cape Stosch Formation. But already in 1930 Rosenkrantz showed that beds of sandstone containing *Ophiceras* were intercalated with the conglomerates occurring in the formation and that it, therefore, was of Early Triassic age. The name was rarely used in subsequent literature and TROELSEN (1956), in the *Lexique Stratigraphique Internatonal*, gave the age as "Permian (Triassic)". It is, without doubt, synonymous with the Wordie Creek Formation discussed below.

Wordie Creek Formation

The name Wordie Creek Formation was proposed by KOCH (1929a, p. 118; 1929b, p. 249) for a unit of white and red sandstone and shale, about 100 m thick, containing bivalves and "about 10 ammonites". These fossiliferous beds were first discovered by WORDIE (1927, p. 253), who did not name them. When he established the formation, KOCH did not furnish any information on the location of the type section. A small sketch map published by ROSENKRANTZ (1932, fig. 1) shows Wordie Creek in the location of what KOCH (1931) had called River 16, but NIELSEN (1935, pl. 1) showed Wordie Creek in the position of KOCH's River 15. In his major paper on Carboniferous and Triassic stratigraphy KOCH (1931, pl. 1) did not show on his map the positions of either Wordie Creek or Foldvik Creek. The river which ROSENKRANTZ (1932) later identified as Wordie Creek was called Blue River by KOCH (1931) and he left River 15, later named Wordie Creek by EIGIL NIELSEN, unnamed. On most later maps KOCH's 1931 usage is perpetuated and River 16 is called Blue River, or Blåelv in Danish. The river is called Blåelv on Geodetisk Institut map sheet 73 Ø. 1, Hold with Hope, 1:250,000, published in 1952. Thus, obviously the name Wordie Creek is now obsolete.

This fact notwithstanding the name Wordie Creek Formation which had long fallen into disuse has more recently been revived by TRÜMPY (1960; 1961; *in* CALLOMON, DONOVAN, & TRÜMPY, 1972), BIRKELUND & PERCH-NIELSEN (1969), and by GRASMÜCK & TRÜMPY (1969), all of whom applied the name to Lower Triassic rocks in Jameson Land and other areas, several hundred kilometers south of Kap Stosch. The name was also used for the earliest Triassic beds of the Kap Stosch area by HALLER in his comprehensive volume on the tectonic map of East Greenland (1970).

More recently, PERCH-NIELSEN *et al.* (1974) have definitely identified Blåelv (River 16) as type locality of the Wordie Creek Formation, but did not describe the type section where the thickness of the formation remains unknown. We, ourselves, studied only the lowermost 80 or 90 meters of the formation, in most localities less. In view of the uncertainty about the position of the upper boundary of the formation in the type section, and in the Kap Stosch area in general, we here refrain from using the name Wordie Creek Formation for any of the Triassic rocks studied by us. In view of certain differences in the lithology of the basal Triassic rocks southwest and southeast of Kap Stosch, we are not even certain that they should be included in one and the same formation.

The mixed faunas

It is now necessary to discuss the historical development of views on the mixed Permian-Triassic faunas which are the real core of our problem. We do not refer here to the occurrence of the so-called "white blocks" in conglomerates intercalated in beds bearing an *Ophiceras* fauna, the so-called, now obsolete, Cape Stosch Formation. We have in mind the common occurrence, above the Permian-Triassic boundary, of associations of clearly Permian faunal elements with true ophiceratids and *Otoceras*.

The first mention of such an occurrence was by SPATH (1930, p. 69). After listing a fauna containing species of *Ophiceras*, *Glyptophiceras*, *Vishnuites*, and *Claraia*, he stated: "There is also a *Productus* marked as coming from the same altitude, but this may be out of the Drift." These fossils had been collected by WORDIE. It should be remembered that at the time of SPATH's writing the only beds from which a "*Productus*" could have been derived were regarded as Lower Carboniferous, or, possibly, uppermost Devonian, according to KOCH. KOCH, in 1931 (p. 79), listed *Productus* spines and fragments, together with the bryozoans *Synocladia*, ?*Acanthocladia*, *Fenestella*, and *Stenopora* as members of a fauna containing *Otoceras*, *Ophiceras*, and *Glyptophiceras*[1]). KOCH

[1]) When SPATH (1930, p. 33) introduced the genus *Glyptophiceras* he had before him a collection of Early Triassic invertebrates from East Greenland, mainly from Kap Stosch. These collections contained an evolute ammonoid with sigmoidal ribs and a rounded venter. However, he selected as the type of his new genus *Xenodiscus aequicostatus* DIENER (1913, p. 6, pl. 2, figs. 10a, b) from Pastannah, Kashmir. TOZER (1969) has concluded on the basis of a reevaluation of some of the Pastannah ammonoids and especially of the identification of a specimen of "*Pseudomonotis*" *himaica* BITTNER attached to a Pastannah ammonoid specimen in the British Museum (Natural History) that this fauna is of mid-Scythian age, or the Smithian of his nomenclature. Recently Mr. H. M. KAPOOR of the Indian Geological Survey has restudied and collected the Pastannah area. In the collections sent to KUMMEL the fauna with the "*Glyptophiceras*" of SPATH has also yielded *Owenites* and *Meekoceras*, thus completely confirming TOZER's conclusions. The conodonts studied by W. C. SWEET also confirm this age assignement (see Appendix). TRÜMPY (1969, p. 86) in a study of early Triassic ammonoids from northern Jameson Land, East Greenland, introduced the subgenus *Glyptophiceras* (*Hypophiceras*) for the small forms that occur in the lowermost Triassic beds.

A manuscript on the new material from Pastannah is in preparation by KUMMEL & KAPOOR. We do not feel that the needed nomenclatorial revisions should be introduced in this paper and we thus follow the usage of TRÜMPY.

stated that the Paleozoic forms "may originate from older beds that have been redeposited". By the time of KOCH's writing his Foldvik Creek Formation had been moved up into the Upper Carboniferous (FREBOLD, 1931b). Redeposition, therefore, seemed to be the natural answer.

In 1935, SPATH dealt with these "derived Paleozoic elements" (SPATH, 1935, p. 114) in somewhat more detail. On page 106 of the same publication he stated: "The lower *Glyptophiceras* beds (*triviale* zone) have yielded, in addition, some brachiopods and polyzoans which are believed to have been worked up from the underlying (Carboniferous?) rocks ... but if the supposed Palaeozoic fossils are derived from a pre-existing rock when the deposit was laid down, their preservation is not worse than that of the ammonites". On page 98, SPATH mentioned such assemblages from several localities in the area southwest of Kap Stosch (Ekstraelv [= River Zero] and River 1). He also illustrated two slabs showing associations of productids and bryozoans with ophiceratids (SPATH, 1935, pl. 6, fig. 9; pl. 20, fig. 1).

EIGIL NIELSEN (1935, p. 30) briefly described the field occurrences of such faunas in the river he named Ekstraelv (= River Zero) and the occurrence in the beds of *Glyptophiceras* with bryozoans and brachiopods "possibly ... worked up from the underlying rocks".

In the meantime, FREBOLD (1932) had moved part of the "Upper Carboniferous" into the Lower Permian, and ALDINGER (1935), revising the fish fauna of the "*Posidonomya* shale", pleaded for a Late Permian age of the entire late Paleozoic complex, but was finally satisfied to settle for Artinskian.

The matter took a new turn when MILLER & FURNISH (1940) described the ammonoid *Cyclolobus* from the *Martinia* beds of Clavering Ø. The *Martinia* beds were then regarded as the highest unit of the upper Paleozoic sequence and *Cyclolobus* was thought to indicate very latest Permian age. It now appeared that rocks of latest Permian age were overlain by rocks of earliest Triassic age and the conclusion that the Paleozoic faunal elements in the Triassic rocks were redeposited was no longer compelling. It became thinkable that Permian species or genera might have survived for a short span of time in the earliest Triassic.

MAYNC (1942) was the first to consider this as a distinct possibility. He stated that the Upper Permian *Martinia* limestone graded transitionally into the "Eotriassic" *Glyptophiceras* Zone and that this observation might very well be supported by the presence of Permian faunal elements in the Triassic. MAYNC did not discuss the obvious difficulties posed by the presence of boulders of Permian limestone ("white blocks") in Early Triassic conglomerates, although he believed the white blocks to have been derived from youngest Permian "reef limestones".

After 1942, the discussion lagged. In fact, the record of co-occurrence of Paleozoic-type fossils with ophiceratids seems to have been forgotten and remained unmentioned in the large amount of literature written during the 1940's and 1950's on Permian extinctions and their possible causes.

The debate was resumed in 1960 when TRÜMPY reported on the results of a visit to Kap Stosch and especially his investigations of the Permian-Triassic boundary beds in this vicinity (TRÜMPY, 1960). He described that at River 1 and at Ekstraelv [sic = our River Zero] *Glyptophiceras* and *Otoceras* were associated with large numbers of brachiopods, bryozoans, and crinoids that could not be distinguished from those of the underlying Permian *Productus* limestone. He described similar occurrences from Fleming Fjord, 250 km south of Kap Stosch. He concluded that in East Greenland faunas of Permian and Triassic affinities coexisted for a time. On the other hand, TRÜMPY admitted at least the possibility of a stratigraphic break in this area.

In the following year, TRÜMPY again referred briefly to the Kap Stosch section, called attention to the co-occurrence of *Glyptophiceras* and *Otoceras* with Permian-type brachiopods, crinoids, and bryozoans, and added that they "are certainly not derived" (TRÜMPY, 1961).

On the other hand, DUNBAR (1961) pointed out that if there had been an erosional break after the deposition of the highest Permian beds, "brachiopods and bryozoans may have been washed free and become transported as pebbles to be redeposited" in sediments of the advancing Triassic sea.

Later, GRASMÜCK & TRÜMPY (*in* DEFRETIN-LEFRANC *et al.*, 1969, p. 38) reported the occurrence of " 'Permian' benthonic fossils" in lowermost Scythian rocks of Wegener Halvø, 250 km south of Kap Stosch and regarded it as "quite certain that productids and 'Permian' bryozoa occur in primary association with several species of *Glyptophiceras* (*Hypophiceras*) and with true *Otoceras* in the triviale zone of Kap Stosch".

As in other parts of the world where a seemingly unbroken marine sequence across the Permian-Triassic boundary was believed to exist, the problem now was narrowed down to the question of whether or not sedimentation had indeed been continous, or whether there had in fact been a break in very latest Permian time, such as has been established for the Salt Range section by KUMMEL & TEICHERT (1970).

The suggestion of a break between Permian and Triassic in East Greenland found support in FURNISH's worldwide review of species of *Cyclolobus*. On the basis of its stage of sutural evolution FURNISH (1966) regarded the East Greenland species *C. kullingi* as indicative of an early Late Permian age and he assigned the Foldvik Creek Formation a place just above the Guadalupian, thus postulating a stratigraphic break in

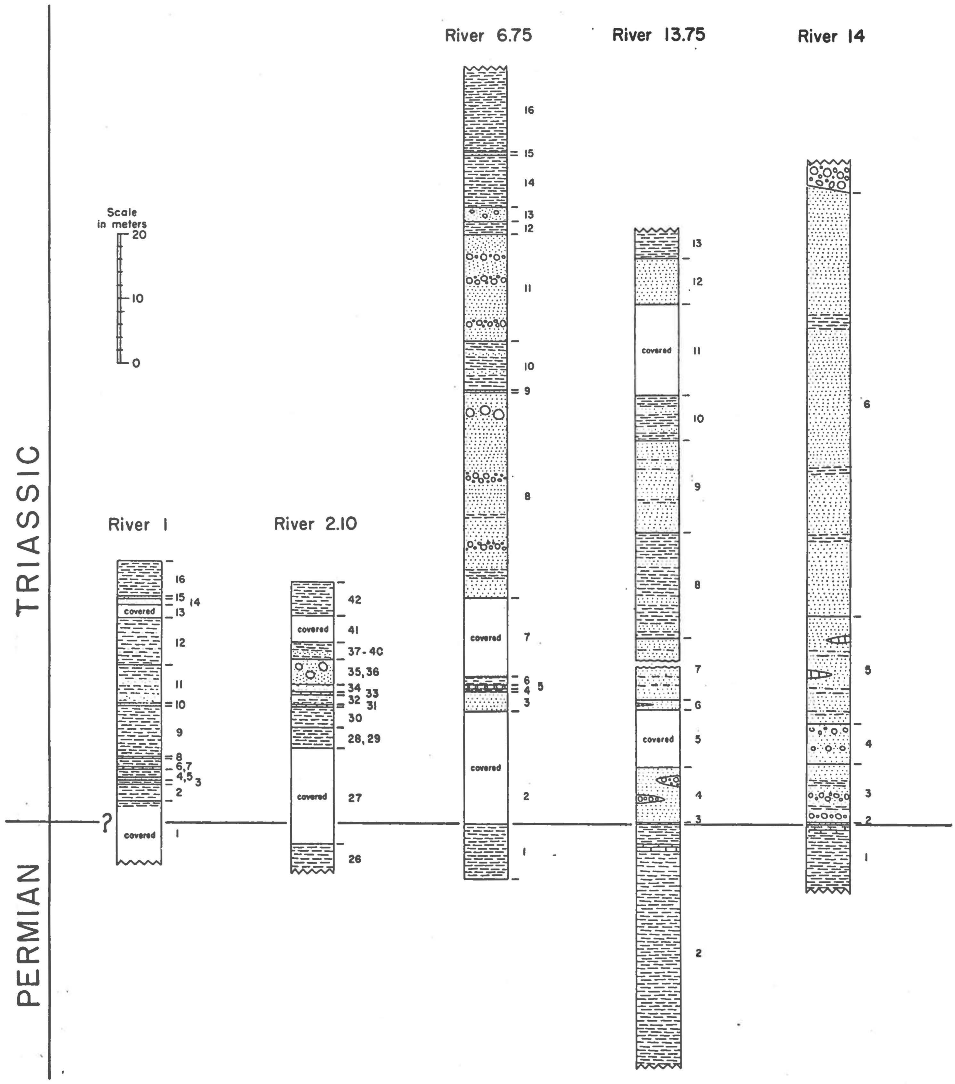

Fig. 3. Stratigraphic sections of Permian-Triassic boundary strata in the Kap Stosch area.

East Greenland that encompasses the Guadalupian, some of his "Chidruan" and all of the Dzhulfian. For the time-stratigraphic interval represented by the Foldvik Creek Formation he proposed a new stage called the Godthaabian (FURNISH, 1966). This was in contrast to the correlation proposed by NASSICHUK *et al.* (1965) who placed the Foldvik Creek in the Dzhulfian Stage. In 1972, TRÜMPY (*in* CALLOMON, DONOVAN, & TRÜMPY, 1972, p. 9) modified somewhat his previous views on the continuity of sedimentation across the Permian-Triassic boundary.

PERMIAN-TRIASSIC BOUNDARY BEDS OF KAP STOSCH AREA

Since our investigations were focused on the Permian-Triassic boundary, only the uppermost part of the Permian and the lowermost part of the Triassic section were investigated in some detail. These included those units (or lithotopes) referred to in previous literature as "*Productus* limestone" and "*Martinia* shale" in the Permian, and the *Glyptophiceras* beds of the Triassic (NIELSEN, 1935). Attention was focused, first, on an area southwest of Kap Stosch, including outcrops in Rivers Zero, 1, and 2; second, on a section of coast southeast of Kap Stosch, essentially between Rivers 6 and 14, (see fig. 3).

Areas southwest of Kap Stosch

Locality Zero

River Zero is the next major river south of KOCH's (1931) River 1. It was called Ekstraelv (Extra River) by NIELSEN (1935), but in 1952, on Geodetisk Institut map sheet 73 Ø.1, Hold with Hope, 1:250,000, the name Ekstraelv was attached to a larger river that follows next to the south. A visit to the banks of this river showed that no Permian or Triassic outcrops were present. We, therefore, renamed NIELSEN's "Ekstraelv" River Zero.

In this locality, outcrops and float blocks of fossiliferous rocks are found mostly on the north bank of the river, but float blocks are also found halfway up the slope on the south bank. This locality is situated approximately 2.5–3 km from the mouth of River Zero (NIELSEN, 1935, p. 29). Everywhere the outcrops are badly disturbed by solifluction, although these processes seem to work very slowly, because by and large the north bank locality in 1967 (Fig. 4) looked very much as it did when EIGIL NIELSEN visited it in 1932 and 1933 (NIELSEN, 1935, p. 31, fig. 4).

The north bank is about 50 m high, but a measurable section exists only in the lowermost part where "*Martinia* shale" is exposed (Fig. 4). This consists of shale and fossiliferous siltstone in which *Chonetina noenygaardi* DUNBAR and *Martinia greenlandica* DUNBAR are the most common fossils. Less common is *Liosotella hemispherica* DUNBAR. Total thickness of these outcrops is about 12 m.

No outcrops are present between the top of this section and the top of the river bank. However, at about 25 m and again at 47 m above the river bed, blocks of calcareous arkosic sandstone of medium gray color, weathering brownish gray to yellowish gray, occur which contain

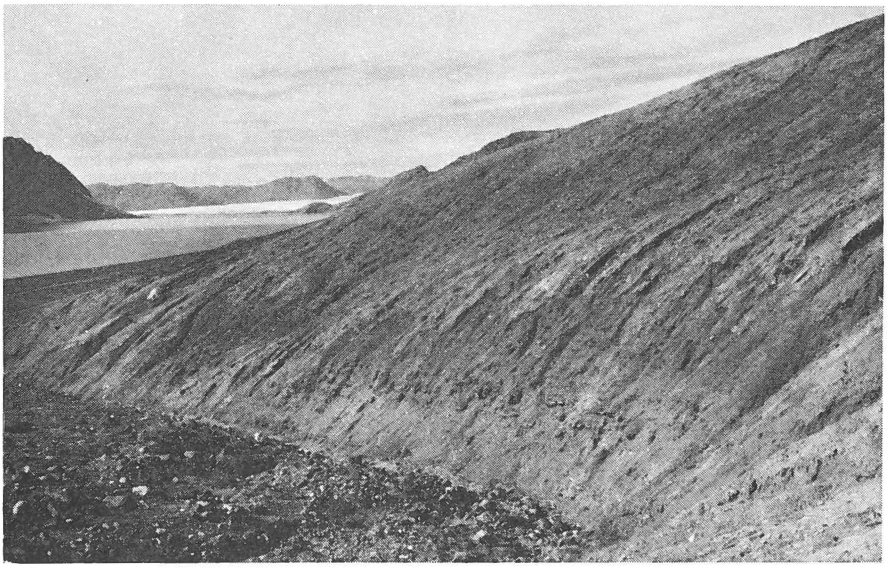

Fig. 4. Permian-Triassic strata exposed along north bank of River Zero. The outcrops in the lower part of the slope are *Martinia* shale.

an admixture of specimens of *Glyptophiceras* (*Hypophiceras*) *triviale* SPATH (TRÜMPY, 1969) with Permian forms essentially similar to species in the "*Martinia* shale" and the "*Productus* limestone" which crop out in Rivers 1 and 2 (Pl. 1, fig. 1; Pl. 2, fig. 1; Pl. 3, fig. 1; Pl. 4, fig. 1). This rock is very rich in bryozoan fragments, mostly Trepostomata, but also fenestrate forms (Pl. 14, fig. 2). The Bryozoa have not yet been studied. It is worth noting that the surface of many colonies is exceedingly well preserved, though others are noticeably abraded.

Most brachiopods in these blocks are so badly broken that few fragments can be identified with much confidence. Among species that are possibly present are *Rhipidomella* sp. ind., *Chonetina noenygaardi* DUNBAR, *Liosotella hemispherica* DUNBAR, *Pleurohorridonia* sp. ind., ?*Spiriferella keilhavii* (VON BUCH), ?*Punctospirifer* sp. ind., *Martinia greenlandica* DUNBAR, and several other unidentifiable productids and spiriferids.

As seen in thin sections, the rock consists mainly of angular to subangular quartz grains that are poorly sorted and up to 0.7 mm in diameter (Pl. 14, fig. 5). Glauconite was observed in at least one thin section, out of a total of 9. In addition to the fossils identified megascopically, small rugose corals and echinoid spines, about 1.5 mm in diameter, were seen in thin sections (Pl. 14, fig. 3).

These blocks at the top of the river bank probably represent the disturbed remnants of a once continuous hard, resistant bed.

About 5 m below this level conspicuous "cannon ball" concretions were found on the surface or embedded in the soil. These are either spherical, or very nearly so, and consist of calcareous arkosic sandstone, with a pebble of calcareous micaceous siltstone as a core. The diameter of these spherical concretions averages about 15 cm, that of the pebble core varies from 5 to 8 or 9 cm. Similar "cannon ball" concretions were found at various localities in the area southwest of Kap Stosch, always at no great distance above the base of the Triassic sequence, but it could not be established with certainty, if these occurrences could be exactly correlated.

Blocks lower down the slope and at the bottom of the river possibly are derived from a similar layer to the one near the top of the bank, but in a somewhat lower stratigraphic position. They contain indeterminable bryozoan, productid, and spiriferid remains, and differ from the upper blocks in having more crinoid stems.

One block was found to represent a unique facies, not seen elsewhere. It is a coquina of *Bellerophon* shells, many of them seemingly undamaged or showing little damage, but many shells are broken into fragments. The largest shells have a diameter of approximately 15 mm. In addition, this rock contains a few trepostomatous bryozoans, some unidentifiable brachiopod fragments, and some fish spines and scales. Of additional interest are flat pebbles of light, olive-gray, calcareous argillite that seem to have been embedded edgewise in random orientation. They appear to be unfossiliferous. The largest pebble seen is 8 cm long and 2 cm wide. Specimens of *Bellerophon* also occur in the float blocks near the top of the river bank, but never in coquinoid concentrations as described here. Gastropods are rare in Permian rocks of East Greenland and none have been formally described. Unfortunately, the specimens from River Zero are not well enough preserved to warrant formal description.

On the south side of the river, fossiliferous blocks were found from river level up to about halfway up the river bank which is here somewhat lower than the north bank. In the river bed we collected blocks of arenaceous limestone, very rich in fossil fragments and showing impressions of small ammonoid shells. The Permian fossils in these blocks include trepostomatous Bryozoa, *Camerophoria* sp., fragments of large spiriferids, including possibly *Spiriferella keilhavii*, a bivalve fragment, possibly representing *Pseudomonotis speluncaria* (SCHLOTHEIM) (see NEWELL, 1955, p. 18), crinoid stems, 5 mm in diameter, and a large bradyodont tooth about 15 mm in diameter, which seems to be unlike any previously described from the Permian of East Greenland.

The blocks found halfway up the bank in this locality consist of light gray, arkosic, calcareous sandstone, in part rich in small ammonoid shells, and contain recognizable Permian fossils such as abundant trepostomatous, and some fenestrate Bryozoa, *Camerophoria* sp., and occasional indeterminable fragments of productid and spiriferid brachiopods.

It is likely that all these blocks are derived from one or two once continuous beds halfway up the river bank or in the upper part of the bank. If this is so, it may be surmised that these beds were once continuous with the corresponding beds, containing similar fossils, on the north bank of the river.

It seems that when NIELSEN visited River Zero ("Extraelv") in 1932 and 1933 the outcrops must have been somewhat less disturbed, for he mentions that the "*Martinia* limestone ... is overlain ... by the lower *Glyptophiceras* zone". He continues: "Only the lowermost part of the *Glyptophiceras* zone is exposed in the northern bank ... the lowermost 5–6 m of the lower *Glyptophiceras* zone are made up of loose, grey sandstone interstratified with harder, calcareous sandstone bands teeming with Bryozoans, Brachiopods, *Glyptophiceras*, etc. A little higher up the Bryozoans and the Brachiopods which have possibly been worked up from the underlying rocks, decrease in number" (NIELSEN, 1935, p. 30). There is, thus, little doubt that NIELSEN was able to observe in outcrops at least some rock types we found only as float blocks. Similarly, on the southern bank of the river, the rock exposures must have been better in NIELSEN's time than at the time of our visit in 1967.

Stratigraphic Section on North Side of River Zero

Unit		Thickness (meters)
Undivided Permian-Triassic rocks		
10	Covered, upper 5 m contains abundant scree of hard blocks of calcareous sandstone containing *Glyptophiceras* (*Hypophiceras*) and assorted Permian invertebrates (see text).	34.75
Martinia Shale		
9	Shale, medium gray, silty, micaceous, abundant *Neogondolella rosenkrantzi*, some *Xaniognathus* sp..........	6.0
8	Siltstone, brown, micaceous, forms hard band on slope .	0.3
7	Shale, brownish gray, silty, micaceous................	0.5
6	Siltstone, light brownish gray, hard, forming conspicuous ledge; contains brachiopods and *Neogondolella rosenkrantzi*..	0.15

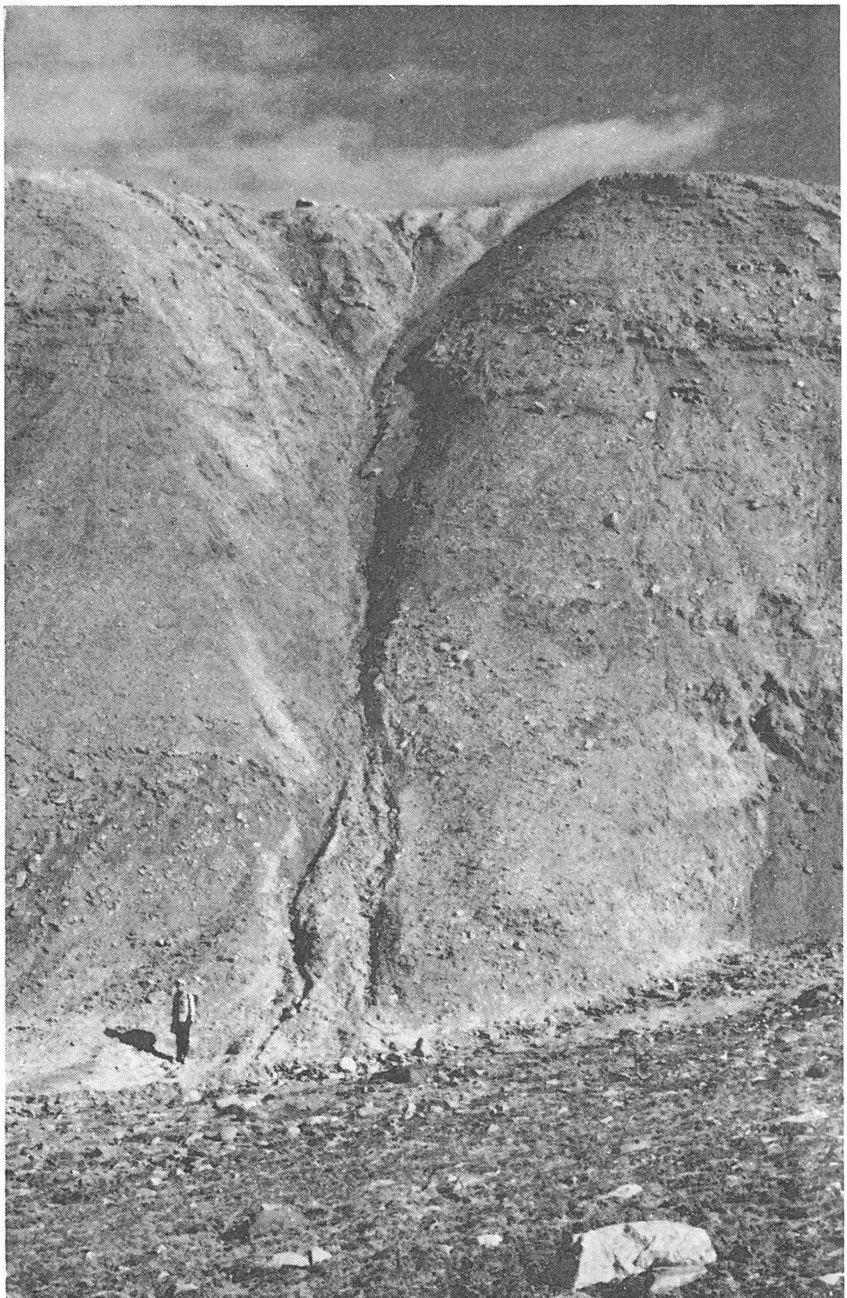

Fig. 5. Permian-Triassic strata exposed along north bank of River 1 (location of the measured section, Locality 1).

5	Shale, gray, micaceous with a few hard silty layers and some calcareous nodules	0.9
4	Shale, silty, medium gray, micaceous, slightly more compacted than bed 3	0.2
3	Shale, light olive gray, silty micaceous	1.9
2	Shale, medium to dark gray, silty, hard, micaceous; contains plant and brachiopod fragments, and the conodont *Neogondolella rosenkrantzi*	0.2
1	Limestone, medium gray, sandy, medium crystalline; contains comminuted shell fragments	0.1

Locality 1

The condition of the outcrops at River 1 is similar to those in River Zero. In one place, part of a section is exposed on the north bank (Fig. 5) but it is much slumped, so that a measured section of 34 meters contains many uncertainties. The section begins with about 30 cm of bituminous shale with large phosphatic concretions, up to 15 cm in diameter. At about 3 m dark gray shale contains stringers of glossy coal (unit 3). Fish spines were observed a little over 3 m from the base (unit 4), and the first ophiceratids and *Otoceras* at about 4.30 m in a 10 cm band of gray, silty limestone.

In unit 9, between about 3 and 4.40 m above the ophiceratid horizon a calcareous, fine-grained, laminated sandstone bed of grayish-orange color occurs that contains tiny fragments of bryozoans, including one fenestrate form. Most fragments are less than 5 mm long. While bryozoan fragments are rather abundant, only very few and damaged, unidentifiable, brachiopod remains are present.

Above this bed the section consists almost entirely of shale and siltstone. However, between about 14 and 20 m higher up intercalations of fine-grained, olive-gray, micaceous sandstone occur, from one of which very small bryozoan fragments and one broken productid spine were recovered (unit 12).

Units 4, 5, 6, and 8 contain tightly packed laminar bodies (Fig. 6; Pl. 14, fig. 6; Pl. 15, fig. 2) which bear a superficial resemblance to phylloid algae as described by Pray & Wray (1963), Wray (1964, 1968), Heckel & Cocke (1969), and other authors. However, John L. Wray (written communication, April 12, 1974) to whom specimens were sent for study does not think that they are in fact phylloid algae, although he does not exclude the possibility that "they could indeed be algae of some unknown affinity".

In addition, the same beds contain rare specimens of *Posidonia*

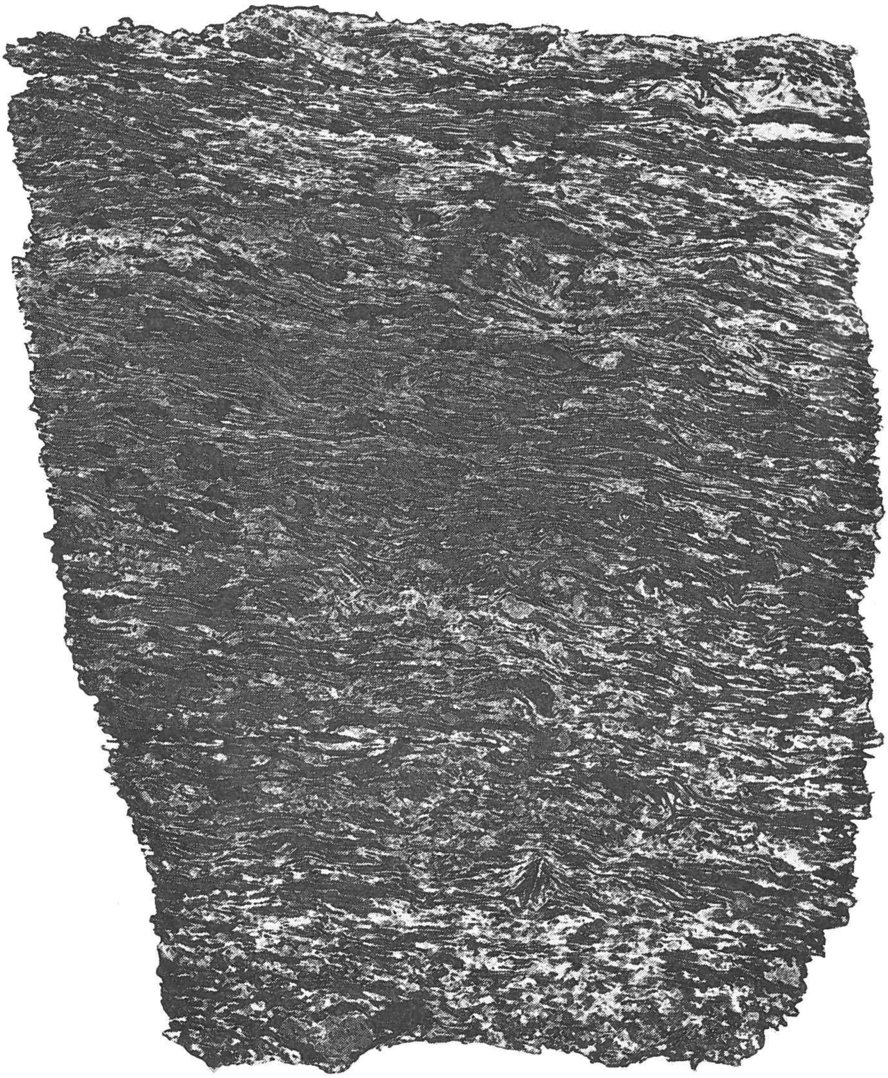

Fig. 6. Layer of tightly packed organic laminae resembling phylloid algae, locality 1, unit 4. Acetate peel. ×3.8.

and, more abundantly, small serpulids which are similar to species of the genus *Spirorbula*, described by K. B. NIELSEN (1931) from the Paleocene of Denmark.

In the interval of unit 9 we collected a few loose blocks of an almost identical lithology to that of unit 8 which, in addition to the abovementioned fossils, also contain small bryozoan fragments, both trepostomatous and fenestrate, small ammonoid shells, long, slender echinoid spines, and one poorly preserved bivalve that almost certainly represents *Pseudomonotis speluncaria.*

In addition, some beds under the microscope show very fine irregular laminations cementing small fossil and rock fragments. These are interpreted as being of stromatolitic nature.

In the lower part of River 1 there are good exposures of "*Productus* limestone" which is here about 2 m thick and where a large collection of Bryozoa and brachiopods was obtained. Outcrops above the "*Productus* limestone" are much disturbed by solifluction. Just above the top of the "*Productus* limestone" the slope is strewn with limestone blocks of light olive gray color, containing abundant trepostomatous and fenestrate Bryozoa but few or no brachiopods. These continue to a vertical altitude of about 6 m above the "*Productus* limestone". At an altitude of about 10 m the ground is covered with thin slabs of a coquinoid limestone consisting mostly of *Glyptophiceras* (*Hypophiceras*) *triviale* SPATH, in addition to fragments of trepostomatous and fenestrate Bryozoa, brachiopod fragments, including productid spines, and ?*Posidonia* (Pl. 5, fig. 1).

Our measurements of the section along the north side of River 1 are as follows:

Stratigraphic Section at River 1

Unit		Thickness (meters)
Lower Triassic		
16	Siltstone, with claystone units, light yellowish brown, highly micaceous, laminated and fissile; contains poorly preserved plant fragments, *Claraia*, *Neogondolella carinata*, *Anchignathodus typicalis*, and *Ellisonia triassica* ..	5.5
15	Sandstone, like bed 14 but more thinly bedded	0.3
14	Sandstone, yellowish gray, brownish weathering, somewhat arkosic and very micaceous, slightly calcareous; massive, friable; contains cannon ball concretions of calcareous sandstone, with clay ball centers	0.8
13	Covered	2.0
12	Siltstone, light olive gray, highly micaceous, thinly laminated and, in places, cross-laminated; contains abundant small pyrite spherules, up to 0.3 mm diameter, productid spines, bryozoan and bivalve fragments, and *Neogondolella carinata*	7.0
11	Shale, light olive gray, with some 1–2 cm beds of micaceous siltstone and fine sandstone; contains *Neogondolella carinata*	5.5

10	Sandstone, dark gray, micaceous, friable; contains small fish scale fragments and *Negondolella carinata*	0.1
9	Shale, light olive gray, micaceous; contains fenestrate bryozoans, lingulids, *Claraia* sp., small gastropods, ammonoid fragments, small echinoid spines, *Neogondolella carinata*, and *Anchignathodus typicalis*; in middle of unit thin, laminated, fine-grained sandstone bed with tiny fragments of bryozoans	7.5
8	Layer of tightly packed laminar bodies (?algae), light olive gray; in addition to the algae abundant angular to subangular quartz grains up to 0.3 mm diameter, biotite and muscovite flakes, and small pyrite spherules, 0.1–0.3 mm in diameter; contains ?*Posidonia*, small serpulids (cf. *Spirorbula* NIELSEN), crushed ammonoid shells, *Neogondolella carinata*, and abundant *Anchignathodus typicalis*	6.5
7	Shale, light olive gray, clayey, contains *Neogondolella carinata*, *Anchignathodus typicalis*	0.8
6	Limestone, light olive gray, rather tightly packed laminar bodies (?algae) in a matrix of aphanitic limestone; very few minor quartz grains; grades downward into sandy limestone with coalified wood fragments; contains *Glyptophiceras* (*Hypophiceras*), *Otoceras*, and fish remains....	0.1
5	Limestone, light olive gray, dolomitic?; a peculiar rock type consisting of about 40 $^{0}/_{0}$ of grains of aphanitic dolomitic limestone of irregular, mostly angular shape, supported by stromatolitic structures (Pl. 15, fig. 1), in places by sparry calcite; contains *Neogondolella carinata* and *Anchignathodus typicalis*	1.0
4	Limestone, medium light gray, aphanitic matrix with about 20 $^{0}/_{0}$ of angular to subangular quartz grains (max. diam. about 0.15 mm); abundant fragments of thin, laminar bodies (?algae), generally not more than 1 mm long	0.1
3	Shale, dark gray, micaceous; thin, glassy coal stringers at top of bed	0.5
2	Shale, medium gray, soft, concretions in upper part; contains *Neogondolella carinata*	2.4
1	Shale, bituminous, with phosphatic concretions; contains *Neogondolella carinata*, *Anchignathodus typicalis*	0.3

Locality 2

In River 2 the Permian-Triassic boundary is not exposed. The Permian sequence begins with a coarse conglomerate that is at least 100 m thick. It is best exposed in a deep gorge cut into it by River 2. Above the conglomerate the following section was measured:

Stratigraphic Section on North Side of River 2

Unit		Thickness (meters)
Permian		
8	Dark shale, very strongly weathered, thickness unknown	?
7	"*Productus* limestone". Limestone yellowish gray, thin-bedded, but forming one massive ledge, richly fossiliferous, especially in the uppermost 25–30 cm. The fauna is listed below	1.4
6	"*Posidonia* shale". Alternation of shale and fissile siltstone, generally brownish gray, with occasional intercalations of argillaceous limestone bands, up to 10 cm thick and very finely laminated; contains large numbers of *Posidonia permica* NEWELL and of *Prographularia groenlandica* (ROSENKRANTZ), and two kinds of hook-shaped fossils, probably arm hooks of *Prographularia*	23.8
5	Covered interval (solifluction)	5.0
4	Dolomite, light olive gray, thin to medium-bedded, but weathering massively in parts; unfossiliferous; 40–50 cm below top occasional intraformational pebbles occur	6.8
3	Alternating beds of massive gypsum, finely laminated gypsum and dolomite	14.0
2	Covered interval (solifluction) about	25.0
1	Basal conglomerate, not studied in detail. Top part of conglomerate unit rather fine-grained with pebbles up to 5–6 cm in diameter derived from metamorphic basement, Proterozoic Eleonore Bay Group, and from Cambrian and Ordovician formations; estimated	100
	Total circa	176

To the total of 176 m an unknown thickness of shale above the dark shale bed above the "*Productus* limestone" unit must be added.

In spite of the abundance of fossils in the "*Productus* limestone" unit, the range in terms of taxonomic units is not great and several hours of intensive collecting by two persons yielded only the following species of brachiopods:

Streptorhynchus kempei ANDERSSON
Chonetina noenygaardi DUNBAR
Liosotella sp.
Sowerbina maynci DUNBAR
Muirwoodia greenlandica DUNBAR
Kochiproductus plexicostatus DUNBAR
Spiriferella keilhavii (VON BUCH)
Martinia greenlandica DUNBAR

The uppermost 30 cm of this unit yielded the following corals described by FLÜGEL (1973):

Calophyllum (*Tetralasma*) *punctatum* FLÜGEL
C. (*Groenlandophyllum*) *teicherti* FLÜGEL
?*Cryptophyllum* (?*Tachylasma*) *ponderosum* SCHINDEWOLF

The conodont *Anchignathodus typicalis* occurs abundantly in the same bed, and a well-preserved echinoid spine was seen in thin section (Pl. 14, fig. 1).

In addition large quantities of fragmentary bryozoan skeletons were collected, mostly Trepostomata, but also some fenestrate colonies. Unfortunately, these have not yet been studied and identified.

Above the "*Productus* limestone" unit we observed 1 or 2 m of gray shale, but beyond that there are no more outcrops for nearly 1 km until a hard Triassic conglomerate layer was reached. KULLING (1930, p. 344) described from this same locality a complete section, about 40 m thick, from the Permian into the Triassic to the base of the first conglomerate, but this section is now no longer observable.

It may be of interest to record here the main features of KULLING's section and compare its description with conditions as we found them 38 years later.

KULLING's *(1930) Stratigraphic Section at River 2*
(condensed from Original)

	Thickness (meters)
Sandstone, yellowish gray, with conglomerate beds	200 +
Conglomerate, yellowish gray, about	60
Sandstone, light gray, micaceous	8–10
Shale, gray, with some beds of gray limestone	30

Productus limestone	10
Shale, light green	7
Posidonia beds	14
Limestone, light gray	6
Dolomite with gypsum	9
Conglomerate, reddish brown	160–170

Somewhat tantalizingly, Kulling mentions no fossils, nor does he clearly indicate the position of the Permian-Triassic boundary in the section. However, he states (p. 345) that some boulders in the upper conglomerate unit are probably derived from the underlying *Productus* limestone and that there thus may be a break in sedimentation "below the upper coarse-clastic sediments".

Thus it would seem that in River 2, as previously observed for River Zero, outcrop conditions in the late 1920's and early 1930's must have been far more favorable than we found them in 1967. Unfortunately, the observations made in those years were not recorded in sufficient detail to allow an exact reconstruction of geological events at the transition from the Permian to the Triassic. It may be significant, however, that in Kulling's section the Triassic sequence seems to begin with a conglomerate, no trace of which could be detected at River Zero and River 1.

Locality 2.1

Relatively poor exposures of shale and sandstone are found in a tributary that enters River 2, from the north, approximately 0.5 km west of the measured Permian section in this river. The lowest exposed beds are of Permian age, but the upper part of the section, though containing no identifiable megafossils, does contain abundant Triassic conodonts. Our section from Locality 2.1 follows. Measured units below the *Posidonia* shale are omitted as irrelevant to the present study.

Stratigraphic Section at Locality 2.1

Unit		Thickness (meters)
Lower Triassic		
45	Conglomerate with thin lenticular sandstone beds; pebbles mainly quartz and quartzite, 1–12 cm, a few angular white blocks of dolomite up to 50 cm; rests disconformably on bed 44	6.0
44	Soft thick-bedded sandstone, greenish brown, polygenic but with little mica; sharp irregular boundary	3.0

43	Covered-sandstone scree at top of unit	35.0
42	Shale, olive-gray, finely micaceous, silty, a few hard thin bands; 1.6 m above base; a hard bed of very fine-grained limestone with sole markings (small resting tracks?); contains *Anchignathodus typicalis*	5.3
41	Covered by solifluction	3.8
40	Shale, light olive gray; 30 cm, below top is a 2 cm hard, calcareous sandstone layer with poorly preserved bivalves and *Xaniognathus* sp., *Neogondolella carinata*, and *Anchignathodus typicalis*	1.7
39	Shale, greenish gray, sandy, highly micaceous	0.25
38	Sandstone, micaceous, arkosic, with spherical concretions, very friable with some grayish-brown harder layers; grades into bed 39	.4
37	Clay shale, light olive gray, somewhat micaceous	.15
36	Sandstone, yellowish gray, micaceous, massive but friable; with spherical, hard sandstone concretions with clay centers averaging 20 cm. in diameter	3.2
35	Sandstone, olive gray, micaceous, slightly arkosic, fairly resistant	.5
34	Clay shale, light olive gray; shales slightly more compact at top of unit, shows no sign of weathering; contains *Xaniognathus* sp., *Neogondolella carinata*, *Anchignathodus typicalis*, and ?*Ellisonia triassica*	1.0
33	Limestone, olive gray, brownish at base, gray at top; consists almost entirely of tightly packed laminar bodies resembling phylloid algae, with little aphanitic limestone matrix and a scattering of angular quartz grains up to 0.2 mm in diameter; contains poorly preserved ammonites, bivalves and shell fragments, and *Xaniognathus* sp., abundant *Ellisonia carinata*, and *Anchignathodus typicalis*	0–0.2
32	Limestone, aphanitic, probably argillaceous, clayey, light olive gray; one bed of thin concretionary limestone 20 cm from top of bed; contains *Neogondolella carinata*	1.4
31	Limestone, similar to bed 33, but has tightly packed laminar bodies resembling phylloid algae, more aphanitic limestone matrix and fewer angular quartz grains; contains *Posidonia* sp., *Xaniognathus* sp., abundant *Neogondolella carinata*, and *Anchignathodus typicalis*	0–0.2

30	Clay shale, micaceous, medium gray to light olive gray; contains *Neogondolella carinata*, *Anchignathodus typicalis* and reworked specimens of *Neogondolella rosenkrantzi*	3.4
29 28	Poor outcrops of shale, olive gray, soft, friable, micaceous; contains *Neogondolella carinata*, *Anchignathodus typicalis*, *Ellisonia teicherti*, and *E. gradata*	3.1
27	Covered, probably shale	14.5
Permian		
26	*Posidonia* shale	

It may be assumed that the interval represented by units 27 through 44 corresponds to that part of KULLING's (1930) River 2 section that lies between the top of the *Productus* limestone and the basal yellowish-gray conglomerate, although the discrepancy in given thicknesses for this interval are considerable—38–40 m in KULLING's section, 84 m in our Locality 2.1.

The aggregates of laminar bodies resembling phylloid algae described from units 31 and 33 are similar in every respect to those described from the Triassic rocks of Locality 1, especially from units 8 and 9 of that section. In this locality, the laminar bodies resembling phylloid algae are found in beds lying about 5 to 15 m above the base of the section. In locality 2.1 they lie about 21–23 m above the top of the *Posidonia* shale. No exact correlation can be made, although it does seem that these beds occur in comparable stratigraphic positions.

Summary

To summarize: In the area southwest of Kap Stosch, more particularly in Rivers Zero, 1 and 2, the Permian-Triassic boundary cannot be determined in the field with great accuracy, but lies somewhere in a covered interval at least 10 to 20 m thick. The uppermost exposed beds of Permian age are usually quite fossiliferous, particularly where they appear in the *Productus* limestone facies. Then, at some level in the section, the first ophiceratids occur, mostly *Glyptophiceras* (*Hypophiceras*). Associated with these ammonoids, or in beds up to 20 m above their first occurrence, we find abundant bryozoan fragments, shells of brachiopods, crinoid stems, and echinoid spines. Most of these fossils are in a state of severe fragmentation, and very few can be identified as to genus. Those, however, that can be identified, are typical members of the Upper Permian *Productus* limestone fauna. Among these are *Pseudomonotis speluncaria* and *Posidonia* sp.

Area southeast of Kap Stosch

At the cape itself and for about 1 km along the coast southeast of it a basalt sill, about 15 m thick, overlies *Posidonia* shale with a baked contact. While the absence of higher Permian beds, such as occur in River 2, may be due to prebasaltic erosion, it is remarkable that the gypsum and dolomite units that lie between the basal conglomerate and the *Posidonia* shale in the vicinity of River 2 are altogether missing southeast of Kap Stosch. Already 0.5 km southeast of the cape the *Posidonia* shale, about 8 m thick, rests directly on the conglomerate.

There are discontinuous outcrops along the coast farther to the southeast, but all are badly slumped and disturbed by solifluction. The first more or less vertically continuous outcrops are found in the vicinity of Rivers 6 and 7.

Locality 6.75

Locality 6.75 is situated between Rivers 6 and 7, where we measured the following section.

Stratigraphic Section at Locality 6.75

Unit		Thickness (meters)
Lower Triassic		
16	Shale, light olive gray, covered with scree of flattened concretions; near top of unit two thin, olive-gray limestone beds, the lower one yielding two well-preserved specimens of *Otoceras woodwardi boreale* (Pl. 10, figs. 2, 3), a few specimens of *Glyptophiceras* (*Hypophiceras*) and *Anchignathodus typicalis*; upper layer, 4–6 cm thick, is a coquina of bryozoan fragments containing some fragmentary shells of brachiopods, among them *Muirwoodia*, *Kochiproductus*, and ?*Cleiothyridina*	4.0
15	Sandstone, medium gray, hard, micaceous, arkosic, medium grained; has sole marks and interference ripple marks	0.35
14	Shale, light olive gray, micaceous	8.5
13	Sandstone, light olive gray, arkosic, medium to coarse grained, contains small pebbles; quartz grains show undalatory extinction or are composite	2.0
12	Shale, light olive gray, micaceous	2.0

11	Sandstone, gray, medium to coarse, conglomeratic in part, arkosic, not well exposed	16.3
10	Shale, light olive gray, with thin beds of light gray, arkosic, medium-grained sandstone; contains bryozoans, productid spines, indeterminate ammonoids, and *Anchignathodus typicalis*	7.4
9	Sandstone, light olive gray, fine to medium grained, somewhat massive, weathers yellowish brown; arkosic, with subrounded to subangular quartz grains	0.2
8	Sandstone, light gray, medium grained, arkosic, micaceous, with beds of conglomerate containing pebbles up to 10 cm in diameter, cross bedded; a few beds of light olive gray, silty, micaceous shale; in upper part of unit is a bed containing spherical sandstone concretions with clay centers	32.6
7	Covered, patches of sandstone and shale visible	12.6
6	Shale, light olive gray, silty, micaceous, interbedded with platy, micaceous, sandstone	1.4
5	Sandstone, light olive gray to dark gray, thin bedded, arkosic, with pebbles 2–3 mm in diameter	0.7
4	Shale, light olive gray, micaceous, silty	0.15
3	Sandstone, light gray, friable, arkosic, micaceous, massive	2.5
2	Covered, probably mostly light olive gray shale. An isolated sandstone bed near bottom of interval yielded *Neogondolella carinata*, *Anchignathodus typicalis*, *Ellisonia triassica*, and *E. teicherti*	17.0

Upper Permian

1	*Martinia* shale, brownish gray, exposures poor	8.5 (arbitrary base)

Surprisingly, the entire sequence, about 110 m thick, is encompassed by the conodont zone of *Anchignathodus typicalis*. The most interesting part of the section is its topmost unit 16, more than 100 m above the base of the Triassic, which yielded well-preserved specimens of *Glyptophiceras (Hypophiceras) triviale* Spath and *Otoceras woodwardi boreale* Spath. Close to the top of the unit is a coquinoid bed of bryozoan and brachiopod fragments, among which productid spines are very numerous. In this section, the foraminifer *Colaniella*, rugose corals, and ostracodes were seen. Among larger, fragmentary brachiopods the genera *Muirwoodia*, *Kochiproductus*, and *?Cleiothyridina* could be identified. In general appearance this bed somewhat resembles the lose blocks found in the upper 5 m of unit 10 at River Zero.

Locality 8.25

Between our Locality 6.75 and the vicinity of River 14 Permian and Triassic rocks crop out in many places but, because of intense solifluction, coherent sections, especially across the Permian-Triassic boundary, are rare, although the boundary strata can be observed in a few places.

One such locality was examined between Rivers 8 and 9, but closer to River 8, so we gave it the number 8.25. Here, the Permian-Triassic boundary is well exposed and is marked by a sharp lithological change from the soft shale of the Permian "*Martinia* shale" to hard, coarse-grained, arkosic sandstone. At the base of this sandstone unit are pockets of conglomerate mostly composed of flat limestone pebbles with greatest diameters of 3 to 4 cm, but many much smaller. In between the pebbles occur specimens of *Glyptophiceras* (*Hypophiceras*) *triviale* which are, in places, quite crowded. In addition, occasional bryozoan fragments and remains of productid brachiopods are found (Pl. 6, fig. 1).

Two meters below the base of this sandstone and its conglomeratic pockets the *Martinia* shale, which here is mottled reddish brown and light olive gray, contains a fossiliferous bed with the chonetid *Tornquistia toulai* (Dunbar). One meter below this bed is a 10 cm thick bed of arenaceous limestone which is richly fossiliferous and represents the typical *Productus* limestone facies. It is unlikely that the flat limestone pebbles in the conglomeratic pockets are derived from outcrops of this kind of limestone, because they appear to be unfossiliferous.

The occurrence of *Glyptophiceras* (*Hypophiceras*) *triviale* is considered by us to mark the base of the Triassic System. About 20 to 30 m of basal Triassic arkosic sandstone is exposed in this section, a very monotonous rock type. Higher up, the slope is covered with glacial till.

Locality 8.25 is one of the places where the Permian-Triassic contact is best exposed and most convincing, but the total exposed thickness of section is very small.

River 14 and vicinity

Of considerable interest are two sections in the vicinity of River 14, which is also known as Blåelv (Blue River), as discussed earlier (Fig. 7). Here, we were able to measure two sections, one a short distance to the northwest of River 14, at a locality which we called 13.75, and another one just on top of the southeast bank of River 14 itself. Our

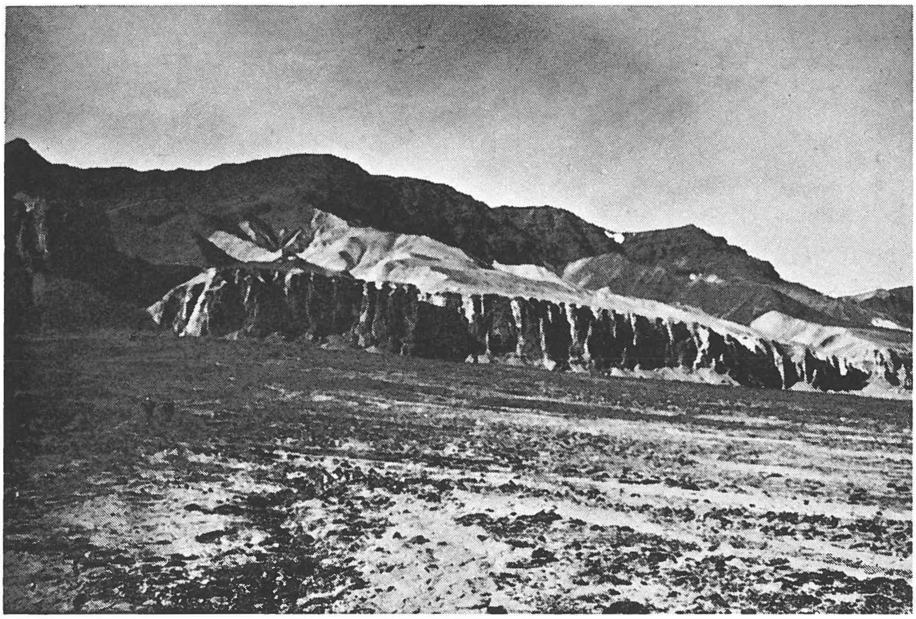

Fig. 7. General view of the area of River 13 (right) and River 14 (left). The light-colored spur in center of picture is "smalle ryg".

locality 13.75 is known among Danish geologists as "smalle ryg" (little ridge), locality 14 as "depot ryg" (depot ridge), but these designations are not found on maps. In both sections, almost the entire Permian is represented beginning with a basal conglomerate, followed first by dolomite, then by a shale sequence, the lower part of which can be identified as representing the *Posidonia* shale facies. In its upper part, the shale can be identified as equivalent to the *Martinia* shale facies. This contains usually one or two limestone intercalations, reminiscent of the *Productus* limestone facies southwest of Kap Stosch, and very rich in Bryozoa and brachiopods which can be easily identified on the basis of the splendid monograph on Permian brachiopods of East Greenland by DUNBAR (1955).

Because of lack of time we did not study the Permian part of the section, of which MAYNC (1942, p. 53–55) has given a brief description. This can be translated into the following condensed succession:

Permian Section at River 14
(adapted from MAYNC, 1942)

Unit		Thickness (meters)
7	*Productus* limestone	0.8
6	Hard, reddish limestone	0.1

5	*Martinia* limestone	30.0
4	*Posidonia* shale	10.0
3	Black shale	0.2
2	Limestone-dolomite unit	7.0
1	Basal conglomerate	100 +

The total thickness, thus, is probably in excess of 150 m. MAYNC does not mention fossils, but from our observations, the assemblages are very much the same as in our Locality 13.75, where, however, the part of the section above the *Posidonia* beds is distinctly more shaly. We would like to call the beds above the *Posidonia* bed *Martinia* shale rather than limestone.

In the section at Loc. 13.75, the shale is abruptly overlain by a conglomerate (unit 3 of our section) which along the measured section is 30 cm thick, but which seemed to be lenticular along the strike. It consists of fairly well rounded quartz pebbles up to 3 cm in diameter, and, mostly smaller, angular pebbles of pink feldspar. In addition, this conglomerate contains badly damaged shells of large productids, fragments of trepostomatous Bryozoa, and we collected one fenestrate bryozoan forming an encrustation on a quartz pebble (Pl. 8, fig. 1). The productids belong to one of the large productid genera described by DUNBAR (1955), most probably either *Pleurohorridonia* or *Sowerbina*, and to ?*Muirwoodia*. We also have one fragment of a large spiriferid, most probably *Neospirifer striatoparadoxus*. All of these forms are typical of the *Productus* limestone facies of the underlying Permian. The next 8.5 m are arkosic sandstone, with pockets of arkosic conglomerate containing scattered, broken bryozoan fragments. Although a total of 73 m of section was measured, the attempt was little rewarding because the beds are monotonous sandstone, fine to coarse-grained, and more or less arkosic.

In the River 14 section, the Permian-Triassic boundary is of somewhat similar nature. The uppermost Permian shale of the *Martinia* shale facies is overlain by an arkosic sandstone unit 20 cm thick, which contains conglomerate pockets with bryozoan and brachiopod fragments, including productid spines, together with ophiceratid ammonoids (unit 2).

Between 9 and 15 m above the base of the Triassic (unit 4), we found arkosic sandstone and arkosic conglomerate containing well preserved specimens of *Otoceras woodwardi boreale* along with large numbers of generally poorly preserved Permian fossils such as large crinoid stems, clusters of bryozoans, both trepostomatous and fenestrate, and numbers of brachiopods among which the following could be identified: *Lioso-*

tella grandicosta DUNBAR, *Kochiproductus plexicostatus* DUNBAR, *Pleurohorridonia* ? sp., *Muirwoodia greenlandica* DUNBAR, *Stenoscisma* sp., *Neospirifer striatopunctatus* (TOULA), *Spiriferella keilhavii* (VON BUCH), in addition to two or three unidentifiable genera. All of these species and genera are typical members of the *Productus* limestone and *Martinia* shale associations in the upper part of the underlying Permian sediment, but in the Triassic strata almost all specimens are badly broken.

Above this unit we examined closely a section of additional 81 m of sandstone (units 5 and 6) which, however, proved to be unfossiliferous.

The detailed measured sections at these two localities are as follows.

Stratigraphic Section at River 13.75

Unit		Thickness (meters)
Lower Triassic		
13	Shale, gray-green, with occasional thin bands of siltstone and fine-grained sandstone	50 +
12	Sandstone, medium gray, arkosic, cliff-forming	7.0
11	Covered	14.0
10	Shale, same as bed 8	7.0
9	Sandstone, same as bed 7	14.0
8	Shale, dark gray, with a few hard beds of sandstone up to 10 cm thick	16.0
7	Sandstone, mainly gray, but tan in parts, medium to coarse grained; generally thin bedded, parts platy others shaly, some parts arkosic; unit thick, dull, monotonous; a few poor imprints of ammonites at several levels	104.0
6	Sandstone, gray, coarse, feldspathic, massive, resistant, bench-forming, cross bedded, with lenses of conglomerate, clasts up to 5 mm	1.5
5	Covered, appears to be very friable, very soft sandstone, nonarkosic	8.5
4	Sandstone, olive gray, arkosic, medium grained, slightly arkosic, thin-bedded, slabby in places, with lenticular beds of arkosic conglomerate; contains a few poorly preserved Bryozoa, also a float specimen of a poorly preserved ammonite; for photomicrograph see Plate 15, fig. 5	8.5

3	Conglomerate, arkosic, with clasts of sandstone, quartz, feldspar, and shale up to 5 cm diameter, in fine-grained light gray to greenish gray cement; contains fair number of fragmentary Permian fossils (*Amplexizaphrentis* sp., Bryozoa, large brachiopods, crinoid stems) of poor preservation (Pl. 7, figs. 1–4; Pl. 8, figs. 1, 2; Pl. 11, fig. 1; Pl. 12, fig. 2)	0.3
Upper Permian		
2	*Martinia* Shale. Uniform dark to medium gray shale; contains *Neogondolella rosenkrantzi*	42.0
1	*Posidonia* Shale. Dark brownish gray shale. Flaggy limestone interbedded with shale	6.8

Stratigraphic Section at River 14

Unit		Thickness (meters)
Lower Triassic		
6	Sandstone, very light to light gray and light olive gray, fine- to medium-grained, thin-bedded to platy, micaceous, glauconitic, with interbeds of shale; several poor, indeterminate impressions of ammonoids present	65.0
5	Sandstone, light olive gray, fine- to medium-grained, generally very thin-bedded to shaly, glauconitic, some parts conglomeratic, other parts cross bedded, others laminated; flattened clay pebbles up to 30 cm long, occur throughout; a few beds of hard lenticular limestone up to 30 cm thick	16.0
4	Sandstone, olive gray, conglomeratic with pebbles up to 20 mm in diameter, arkosic, friable, bedding not recognizable; contains small flattened sandstone concretions with clay centers; also fairly abundant fauna of Permian invertebrates—poorly preserved crinoid stems, clusters of Bryozoa, both trepostomatous and fenestrate, and a number of brachiopod species mentioned in the text above. Further, we collected two specimens of *Otoceras woodwardi boreale* and several small unidentifiable ammonoids (*Ophiceras*? sp.) (Pl. 8, fig. 3; Pl. 9, figs. 1–3; Pl. 10, figs. 1, 4; Pl. 11, fig. 2; Pl. 12, figs. 1, 3; Pl. 13, figs. 1–4)	6.0

3	Sandstone, light gray, medium- to coarse-grained, micaceous, glauconitic, thin-bedded, friable; contains some thin (up to 10 cm thick) silt and shale beds; impression of an ammonoid, possibly *Glyptophiceras* (*Hypophiceras*), seen at 6.8 m; above this level abundant clay pebbles, up to 20 cm in diameter	9.0
2	Sandstone, medium-gray, hard, coarse-grained, with lenticular conglomeratic beds; contains fair number of poorly preserved, fragmentary Permian fossils, e. g., Bryozoa and productids, associated with ophiceratids	0.2

Upper Permian
Martinia Shale

1	Shale, light gray, micaceous; gray bryozoan limestone one meter below bed 2	2 + (arbitrary base)

Summary

Along the coast between Rivers 6 and 14, the Permian-Triassic boundary is, at least in several places, much better exposed and, therefore, more sharply defined, than anywhere in the area southwest of Kap Stosch. It is generally characterized by a thin Triassic basal conglomerate, or at least conglomeratic pockets, containing *Glyptophiceras* (*Hypophiceras*) *triviale* Spath. Broken fragments of Permian corals, bryozoans brachiopods, crinoid stems, and echinoid spines (Pl. 15, fig. 6) occur either in this conglomerate or at varying distances above it. The vertical spread of occurrences of Permian fossils in Lower Triassic rocks is considerably greater in this area (up to 100 m) than southwest of Kap Stosch, where it is of the order of 25 m only. Further, in the southeastern sections, *Otoceras* was found in beds containing damaged Permian fossils.

PALEOGEOGRAPHIC AND BIOSTRATIGRAPHIC CONCLUSIONS

Permian paleogeography

The geological province of East Greenland in which the Kap Stosch area is situated, underwent intense orogeny and metamorphism in Silurian and Devonian times, followed by a long period of widespread block faulting that extended into the Early Permian (Haller, 1970, 1971). The Late Permian was a time of relative quiescence, and a transgression of the sea "marked the end of the long-enduring Paleozoic diastrophism" (Haller, 1970, p. 143). The Permian sequence begins with an ubiquitous conglomerate which in the Kap Stosch area is more than 100 m thick, though it is thinner elsewhere (Maync, 1942; Kempter, 1961).

According to Maync (1940, p. 15) this is to be interpreted as a true, basal conglomerate, deposited in rivers and deltas at the front of a sea that transgressed rapidly over a basement of Precambrian and early Paleozoic, partly metamorphosed, rocks. These coarse-clastic rocks are followed by evaporites, shale, sandstone, and limestone which replace each other in a variety of intertonguing and interfingering facies patterns as has been demonstrated by Maync (1942). The most abundantly fossiliferous rocks form the *Productus* limestone facies which has been discussed earlier in this paper. Other fossiliferous facies are known as *Posidonia* shale, *Martinia* shale, and *Martinia* limestone. These facies relationships were first recognized in a general way by Frebold (1932, p. 29).

In Haller's view (1970, p. 141) the extent of this transgression coincides more or less with the area of distribution of present-day occurrences of Upper Permian rocks. In the Kap Stosch area, Haller (1971, p. 323) showed the Permian coastline skirting Kap Stosch, but the coast may well have been somewhat farther west.

Early Triassic palaeogeography

Wherever the contact between Permian and Triassic strata is well exposed—and this is the case only in a few localities southeast of Kap Stosch—the change in lithology at that contact is drastic and abrupt: from the dark-colored shale and siltstone of the Permian *Martinia* Shale facies to coarse-grained, medium gray and brownish arkosic sandstone. In places the boundary is further accentuated by occurrences of thin lenses of conglomerate and by occurrence of the first ophiceratids (*Hypophiceras*). Remains of Permian corals, bryozoans, fragments of brachiopod shells, and occasional crinoid stem pieces are found in these lowest beds and, in the sections seen by us, are fairly common throughout the lowermost 15–20 meters of the arkosic sandstone series. These remains of Permian fossils are locally, but more rarely, found as high in the sequence as 100 m above the base of the Triassic.

In the vicinity of Kap Stosch, Haller (1971, p. 324) drew the western boundary of the Early Triassic sea quite close to the cape and very close to the position he showed for the Late Permian sea. In a diagrammatic section, Vischer (1943, pl. 6; see also Haller, 1971, p. 327) showed the Nørlund Alper as forming the western edge of the Permian and Triassic seas. Along the east side of the Nørlund Alper and Jordanhill, just 15 km west of Kap Stosch, runs one of the most important N–S faults in this part of East Greenland, which became active in the Carboniferous and was subsequently reactivated many times. This is the "post-Devonian main fault" of HALLER (1970, 1971) or "postdevonische Hauptverwerfung" of VISCHER (1943) "along which the truncated Caledonides were successively drowned by the expanding realm of the Scandic maritime regime (HALLER, 1970, p. 137)". Neither the Late Permian nor the Early Triassic seas are likely to have transgressed to the west of this line (VISCHER, 1943, p. 180). The Nørlund Alper are a granite batholith which, along with other mountainous masses to the north and south, has been a positive tectonic element since the late Paleozoic and, thus, supplied sediments to the repeatedly transgressing seas to the east of the main fault.

Early Triassic sedimentation

Field observations strongly suggest that with the change of sedimentary regime in the beginning of Early Triassic time sedimentation occurred at a very rapid rate and tremendous masses of clastic sediment were poured into the area. In the Kap Stosch area, rocks representing the *Ophiceras* Zone (= Wordie Creek Formation) are at least 640 m thick (PERCH-NIELSEN *et al.*, 1974, pl. 17, fig. 3), whereas in most parts of the world, the *Ophiceras* Zone is represented by only a few meters of rock, e. g., by 1.6 to 4.8 m in the Salt Range (KUMMEL & TEICHERT, 1970). Also, at Kap Stosch, one single conodont zone, the *Anchignathodus typicalis* Zone, is upward of 100 m thick, although its exact thickness is not known.

The rocks in this part of the section are mostly arkosic in nature, either sandstone or conglomerate. For the most part, the quartz grains are angular to subangular, more rarely subrounded. Most quartz grains show undulatory extinction, and many are of composite nature, two features suggesting derivation from a metamorphic terrain. Obviously, an uplift must have occurred somewhere close to the end of Permian time, bringing to the surface metamorphic as well as Permian rocks which could be eroded, and whose erosional products accumulated in the thick sedimentary sequence representing the *Ophiceras* Zone in the Kap Stosch area.

It appears that the Permian-age fossils in the Lower Triassic arkosic sandstone were washed out of soft Permian rocks such as the *Martinia* shale facies which underlies the Triassic sediments in most places examined by us in the Kap Stosch area. Another potential source are marly and shaly parts of the *Productus* limestone facies. We recognize two modes of transportation:

1. Some fossils, especially large brachiopods, were transported individually and were damaged in the process. Our collections contain no undamaged larger brachiopods and almost all are very strongly fragmented.

2. Other fossils were transported in armoured mud balls. While we have not seen any original mud balls, impressions of such are not uncommon in the arkosic sandstones (Pl. 9, fig. 1; Pl. 11, figs. 1, 2). In most cases individual fossil fragments are found in the matrix outside the mud ball impressions and these include occasional ammonoid fragments (Pl. 13, figs. 1–4). Some impressions of mud balls, although always only partial ones, suggest that the balls might have reached diameters of 10 cm, or only very slightly more (Pl. 11, fig. 1) and that their shape may have ranged from more or less spherical to short-ellipsoidal.

Mud balls receive a brief mention in most standard textbooks such as those by GRABAU (1924, p. 711) who called them clay boulders, by TWENHOFEL (1932, p. 692) who also used the term clay boulders and gave a number of references to earlier discussions and descriptions, and by PETTIJOHN (1957, p. 193). Additional information on earlier observations may be found in papers by RUDOLF RICHTER (1922, 1924, 1926) who himself contributed to knowledge of clay balls. Among other things, he illustrated the impression of an armored mud ball from Eocene sandstone near Vienna which is very similar to the ones we observed in the Kap Stosch rocks, except that in the Eocene specimen the armor consists of quartz grains, not of fossils (RICHTER, 1926, pl. 7, fig. 2).

Mud balls can form under a variety of conditions, on sea and lake shores, and in rivers. The formation of armored mud balls, in particular, has been studied in detail by BELL (1940), and, more recently, by STANLEY (1969). BELL studied the formation and transportation of such balls in a river bed and established some interesting relationships between the size of the balls and current velocities. The mud balls had been formed in enormous numbers during a flood and their material was derived from six clay beds through which the torrential river passed. Length of transport was over five kilometers. BELL concluded that mud balls in the size range of 10 cm, such as the ones with which we are concerned, indicate a current velocity of about 5 m/sec. STANLEY (1969) studied the formation of armored mud balls in the intertidal zone of the Bay of Fundy where they are being carved out of Pleistocene clay. Most balls here are in the 10 cm range (7.5 to 12 cm) and no balls smaller than 5 cm in diameter were observed. STANLEY recorded that mud balls formed in a fluvial environment tend to display a considerably greater degree of sphericity as compared with those formed in intertidal zones which tend to be ellipsoidal in shape.

Armored mud balls can also form on lake shores (DICKAS & LUNKING, 1968), showing that the effect of tidal currents is not a precondition for their formation. Mud balls formed in lacustrine environment are of ellipsoidal shape like those formed in intertidal zones.

All environments in which mud balls are known to form must have been in existence at, or close to, the shore of the land that supplied the Lower Triassic sediments to the Kap Stosch area and we conclude that the Permian fossils in the arkosic sandstone beds of the lowermost *Ophiceras* Zone were carried to their present places from a nearby shore in the west or northwest either singly or as armors of mud balls that formed by the action of fast flowing river in erosion channels or along the shore in the intertidal zone. The uplift of a sufficiently large area underlain by Permian rocks from which the fossils and mud balls could have been derived, must have taken place during latest Permian time and a hiatus, or paraconformity, therefore, exists between the uppermost Permian and the lowermost Triassic rocks in the Kap Stosch area. The next question to be investigated is that of the length of time represented by this hiatus.

Permian correlations

The history of investigation of the East Greenland rocks now considered to be of Late Permian age has been discussed in this paper in the chapter History of Stratigraphic Concepts. A Late Permian age is documented by the occurrence of the ammonoid *Cyclolobus* (Miller & Furnish, 1940), in the so-called *Martinia* limestone, but when exactly in Late Permian time *Cyclolobus* existed is a matter of discussion (Nassichuk *et al.*, 1965; Furnish, 1966; Furnish & Glenister, 1970).

The stratigraphically highest recorded occurrences of *Cyclolobus* are from about 20 m below the generally accepted Permian-Triassic boundary in the Salt Range (Teichert, 1966; Kummel & Teichert, 1970) and Kashmir (Furnish *et al.*, 1973). Suggestions by Grant (1968, 1970) and Waterhouse (1972) to assign a "middle" Permian age to *Cyclolobus* (including the synonymous *Godthaabites* and *Krafftoceras*) have been rejected by Kummel & Teichert (1970) and Furnish *et al.* (1973). We are convinced the evidence favors the Late Permian age of *Cyclolobus* and its equivalents, although its stratigraphic range does not necessarily extend to the uppermost limits of that system.

Among the youngest Permian rocks known are the Ali Bashi Formation of northern Iran (Teichert, Kummel & Sweet, 1973) and the Changhsing and Talung Formations of southern China (Chao, 1965). None of these formations contains *Cyclolobus* although the Changhsing fauna seems to include a cyclolobid ("*Changhsingoceras*" Chao and Liang, 1965, *nom. nud.*) with a distinctly simpler suture than *Cyclolobus*.

DUNBAR (1961) wrote that "it appears probable that the Permian beds of central East Greenland are essentially contemporaneous with the Chideru [*recte* Chhidru] formation of the Salt Range ...", but KUMMEL & TEICHERT (1970) demonstrated presence of a paraconformity at the top of the Chhidru. They concluded that the stratigraphic break indicated by this paraconformity was "of the magnitude of a stratigraphic stage or, possibly, more ..."

FLÜGEL (1973) studied a Permian coral fauna from East Greenland collected by KUMMEL & TEICHERT and stated that this fauna had a distinctly pre-Dzhulfian aspect. He placed the East Greenland fauna in the lowermost Upper Permian for which he used FURNISH's (1966) term "Godthaabian".

NASSICHUK *et al.* (1965) had pointed out that the East Greenland *Cyclolobus kullingi* has a suture that is simpler than that of Tethyan species, the implication being that it might be older. This has been expressed in a correlation table by FURNISH (1966, p. 269). Although *Cyclolobus* is frequently cited as being indicative of the Dzhulfian Stage, it is worth noting that the genus is extremely rare or absent in the type area of that stage, only one specimen of "*Krafftoceras*" sp. having been reported by RUZHENTSEV and SHEVYREV (*in* RUZHENTSEV & SARYCHEVA, 1965, p. 48).

On the other hand, there seems to be no justification for placing the *Martinia* limestone as low as the Word Formation in Texas, as was done by HARKER & THORSTEINSSON (1960), because one would not expect to find *Cyclolobus*, even a "primitive" species, in the lower Guadalupian.

Triassic correlations

KUMMEL (1972, p. 374–377) has documented in detail the importance of *Otoceras woodwardi boreale* as earliest Triassic zone fossil in East Greenland. He reached the conclusion (p. 389) that "the present distributional pattern of *Otoceras* suggests that this genus became extinct in the Arctic region shortly after the beginning of the Triassic but persisted slightly longer in Tethys".

Coincidentally with the sharp change in sedimentational regime at the beginning of the Triassic, large numbers of small ophiceratids make their appearance which SPATH (1935) described as *Glyptophiceras triviale*. This species was made the type of a new subgenus *Glyptophiceras* (*Hypophiceras*) by TRÜMPY (1969) and we are applying this name in the present paper. However, inasmuch as *Glyptophiceras* (*Hypophiceras*) is unknown outside East Greenland, its value as a zone fossil cannot be assessed. SPATH (1935) and TRÜMPY (1969) regarded the triviale "zone" or "beds" as the basal stratigraphic unit of the Triassic sequence.

KOZUR (1974) on the other hand, transferred the species *triviale* to the genus *Xenodiscus* and regarded the beds containing this species as Permian because of presence of rugose corals, together with Permian Bryozoa, brachiopods, and crinoids. KOZUR (1974, p. 157) also placed the beds with *Otoceras woodwardi boreale* in the Permian. In light of the data presented in the present paper, and of the discussion of the genus *Otoceras* published by KUMMEL (1972), not cited by KOZUR, we reject KOZUR's interpretations as erroneous.

Conclusions

We may now summarize our conclusions in regard to the derivation of the Permian fossils in certain sandstone and conglomerate beds of Triassic age, and our suggestions as to the probable nature of the boundary between the Permian and Triassic Systems in the Kap Stosch area.

These conclusions and suggestions are based on the following observations:

1) Permian fossils occur in different localities from the very base of the Triassic System, as determined by the occurrence of the first ophiceratids, up to a distance of about 80 and 100 m above this base. They represent remains of bryozoans and brachiopods, with minor admixture of fragments of corals, ostracodes, echinoids, and crinoids.

2) Between Rivers 7 and 14, all Permian fossils occur in arkosic sandstone or conglomerate in which they are associated with ophiceratids or *Otoceras*, or both.

3) Almost all Permian fossils are damaged or badly broken into unidentifiable fragments.

4) Those specimens that can be identified belong to species that occur in the typical *Productus* limestone and *Martinia* shale facies of the Upper Permian below.

5) The Permian and Triassic rocks are, in the Kap Stosch area, separated by a hiatus that is documented by paleontological as well as tectonic evidence. This hiatus corresponds to all of the Changhsingian Stage and possibly to part of the Dzhulfian as well.

From these observations we draw the conclusion that the Permian-age fossils in the Early Triassic sediments of the Kap Stosch area do not represent survivors from the Permian into the Triassic, but were redeposited from land areas created by uplifts a short distance west of Kap Stosch in latest Permian time.

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APPENDIX

Conodonts from the Permian-Triassic boundary beds at Kap Stosch, East Greenland

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Six hundred eighty-eight identifiable conodont elements were recovered from 37 of 68 samples that were collected for this purpose in 1967 by TEICHERT & KUMMEL. All samples are from Upper Permian and Lower Triassic strata, and come from seven localities in the vicinity of Kap Stosch, the northernmost end of the Hold with Hope Peninsula, East Greenland. Samples are precisely located in sections that are described elsewhere by TEICHERT & KUMMEL (1976).

Conodont elements in the 37 productive samples studied represent the species identified and enumerated in Table I. The conodont species compose two distinct faunas, an older one with *Neogondolella rosenkrantzi* (BENDER and STOPPEL) and a younger one with *Anchignathodus typicalis* SWEET. I comment on the stratigraphic significance of these faunas separately in the following paragraphs.

Neogondolella rosenkrantzi Fauna

The older of the two conodont faunas recognized is confined to Permian rocks and is dominated by *Neogondolella rosenkrantzi* (BENDER and STOPPEL) (Pl. 16, figs. 10, 11, 12, 13). Types of this species are from the *Posidonia* Shale of the Kap Stosch area (BENDER and STOPPEL, 1965); it is represented in three samples from that unit and in additional samples from the *Productus* limestone and *Martinia* shale. Five specimens of *N. rosenkrantzi* occur also in sample 68KC–30A, together with a single specimen of *Anchignathodus typicalis* and at a level about 1.5 m above the one at which the *A. typicalis* fauna is first represented in the section at Locality 2.1. The specimens of *N. rosenkrantzi* are etched, broken, and very much darker in color than are representatives of the *A. typicalis* fauna in this or adjacent samples, hence we suspect that they have been reworked from older beds.

It is not possible at the present time to attach very great biostratigraphic significance to the occurrence of *Neogondolella rosenkrantzi* in the Permian of East Greenland, despite the fact that elements of this species are distinctive morphologically and are readily separated from those of any other species of *Neogondolella* known. The reason for this is that undoubted representatives of *N. rosenkrantzi* are known at present only from the Kap Stosch area Permian rocks under consideration here. Specimens from the Permian at Rupe del Passo di Burgio, Sicily, referred to *N. rosenkrantzi* by BENDER & STOPPEL (1965), and those from the upper Gerster Formation of Nevada assigned to this species by CLARK & BENHKEN (1971) differ from each other and from the types of *N. rosenkrantzi* in details of outline, arching, development of free blade, and conformation of the posterior part of the undersurface. We are convinced that they do not represent *N. rosenkrantzi.*

Morphologically, elements of *Neogondolella rosenkrantzi* are broadly similar to those of *N. phosphoriensis* (YOUNGQUIST, HAWLEY, & MILLER) and *N. idahoensis* (YOUNGQUIST, HAWLEY, & MILLER), which are probably of Leonardian age, and BEHNKEN (1972) regards *N. rosenkrantzi* as a Guadalupian descendant of *N. idahoensis* (in which he also includes *N. phosphoriensis*). Unfortunately, however, no section has yet produced definite representatives of both *N. idahoensis* and *N. rosenkrantzi* in succession, and Permian neogondolelliform elements are erratic in occurrence and seemingly quite variable in the disposition and development of those morphologic features on which phylogenetic arguments must be based.

It should be noted that none of the numerous specimens of *Neogondolella* in my collections from post-Guadalupian Permian rocks very closely resembles *N. rosenkrantzi.* However, some elements of *N. serrata* (CLARK & ETHINGTON), which ranges through the type Guadalupian of Texas, are reminiscent of *N. rosenkrantzi* in outline, proportions, and development of at least the posterior part of the upper surface. It is thus conceivable that *N. serrata*, *N. rosenkrantzi*, and the Gerster specimens from Nevada assigned to *N. rosenkrantzi* by CLARK and BEHNKEN (1971) are representatives of a single stock of *Neogondolella* that was widespread in the Guadalupian but geographically and ecologically quite variable in morphology. Although such a suggestion can not, of course, be confirmed at this time, a Guadalupian age for *N. rosenkrantzi* and the rocks in which it occurs would not be inconsistent with the conclusions of others, which have been summarized by TEICHERT & KUMMEL (1972) and are discussed again elsewhere in this report.

Anchignathodus typicalis **Fauna**

The younger of the two faunas represented in the Permian and Triassic of East Greenland is that of the *Anchignathodus typicalis* Zone, which "straddles" the Permian-Triassic boundary elsewhere in the world and is approximately coextensive with the Changhsingian and Griesbachian stages (Teichert, Kummel & Sweet, 1973). Components of the *A. typicalis* fauna identified in samples from the Kap Stosch area (Table 1; Pl. 16, figs. 1–9, 14, 15) include *A. typicalis*, *Ellisonia gradata*, *E. teicherti*, *E. triassica*, *Neogondolella carinata*, and *Xaniognathus* sp. The *A. typicalis* fauna ranges in East Greenland from a level at least 10 m below that at which definite Triassic fossils first occur in sections at three localities (1, 2.1, 6.75) to a point some 90 m above a horizon with Triassic ammonoids in the section at Locality 6.75. An unknown thickness of rock separates the earliest representatives of the *A. typicalis* fauna from the youngest rocks with specimens of *N. rosenkrantzi*, although, as pointed out previously, one sample (68KC–30A), from Locality 2.1 has yielded an admixture of elements referable to *N. rosenkrantzi* and *A. typicalis*.

Late Permian and Early Triassic components of the *Anchignathodus typicalis* fauna are closely similar. The typical subspecies of *Neogondolella carinata*, which is the one represented in our collections from Kap Stosch, does not appear in northwestern Iran until a few meters below the top of the Ali Bashi Formation, and the Ali Bashi has yielded the youngest Permian conodonts thus far known (Teichert, Kummel & Sweet, 1973). Consequently, if any part of the *A. typicalis* fauna of East Greenland is Permian, it is likely that only the very latest part of that system is represented. In short, it is probable that our specimens of the *A. typicalis* association from East Greenland are mostly, if not entirely, from the upper (i. e., Griesbachian) rather than the lower (i. e., Changhsingian) part of the *A. typicalis* Zone.

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Table 1. *Distribution of Conodonts by Section and Sample*

Locality and Sample No.		*Neogondolella rosenkrantzi*	*Xaniognathus sp.*	*Neogondolella carinata*	*Anchignathodus typicalis*	*Ellisonia triassica*	*Ellisonia teicherti*	*Ellisonia gradata*
		Conodont species						
LOCALITY 0								
	68KA–2	1						
	68KA–6	4						
	68KA–9A	37	3					
T67–72 =	68KK–2							
LOCALITY 1								
	68KB–1			1	4			
	68KB–2			1				
	68KB–5			6	1			
	68KB–7			6	2			
	68KB–8B			1	15			
	68KB–9A			1	1			
	68KB–10			1	2			
	68KB–11A			8				
	68KB–11B			1				
	68KB–12			1				
	68KB–16A			1				
	68KB–16B			1	11	1		
LOCALITY 1.1								
	68KC–1		5	47	13		4	9
LOCALITY 2								
T67–83	68KK–1	115						
LOCALITY 2.1								
	68KC–28–29			25	4		1	1
	68KC–30A	5*			1			
	68KC–30B				5			
	68KC–30D			1				
	68KC–31		2	185	19			
	68KC–32B			1				
	68KC–32C			11				
	68KC–33		1	44	19			
	68KC–34		1	6	3	1?		
	68KC–40A				2			
	68KC–40B		1	2	7			
	68KC–42A				2			
LOCALITY 6.75								
	68KD–2			6	13	1	1	
	68KD–10				3			
	68KD–16				2			
LOCALITY 13.75								
	68KE–2A	1						

* Reworked specimens.

PLATES

Plate 1

Fig. 1. Siltstone with abundant *Glyptophiceras* (*Hypophiceras*) and fragments of Bryozoa and brachiopods. Triassic, top of north bank of River 0. ×1. MGUH 13,834.

Fig. 1.

Plate 2

Fig. 1. Sandstone with *Glyptophiceras* (*Hypophiceras*) and abundant fragments of Bryozoa and brachiopods. Triassic, near top of north bank of River 0. ×0.6. MGUH 13,835.

Fig. 1.

Plate 3

Fig. 1. Sandstone with abundant fragments of Bryozoa and brachiopods. Triassic, uppermost 5 m of slope on north bank of River 0. ×0.9. (Field no. T67–72). MGUH 13,836.

Fig. 1.

Plate 4

Fig. 1. Silty limestone with *Glyptophiceras* (*Hypophiceras*) and fragments of Bryozoa and brachiopods. Triassic, at top of north bank of River 0. ×1. (Field no. T67–55). MGUH 13,837.

Fig. 1.

Plate 5

Fig. 1. Siltstone with abundant *Glyptophiceras* (*Hypophiceras*) and fragments of Bryozoa and brachiopods, loose block. Triassic, along lower part of River 1. ×1. (Field no. T67–87). MGUH 13,838.

Fig. 1.

Plate 6

Fig. 1. Fossiliferous hash composed of fragments of bryozoa, brachiopods, and crinoid stems. 3 m below top of *Martinia* shale between Rivers 8 and unnumbered river to the east (loc. 8.25). ×1. (Field no. T67–106). MGUH 13,839.

Fig. 1.

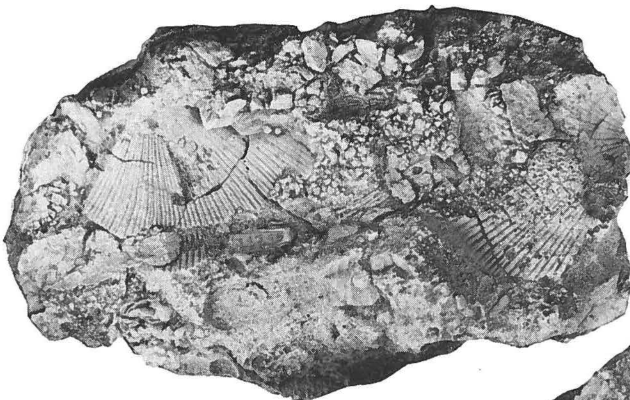
Plate 7

Fig. 1. Conglomeratic arkose with large fragments of brachiopods (productids and *Neospirifer*). Triassic, unit 3, locality 13.75. ×0.9. (Field no. T67–104). MGUH 13,840.

Fig. 2. Conglomeratic arkose with fragments of brachiopods. Triassic, unit 3, locality 13.75. ×0.9. (Field no. T67–104). MGUH 13,841.

Fig. 3. Conglomeratic arkose with fragments of rugose corals, brachiopods, and Bryozoa. Triassic, unit 3, locality 13.75. ×0.9. (Field no. T67–104). MGUH 13,842.

Fig. 4. Conglomeratic arkose with well preserved complete brachiopod (*?Muirwoodia*). Triassic, unit 3, locality 13.75. ×0.9. (Field no. T67–104). MGUH 13,843.



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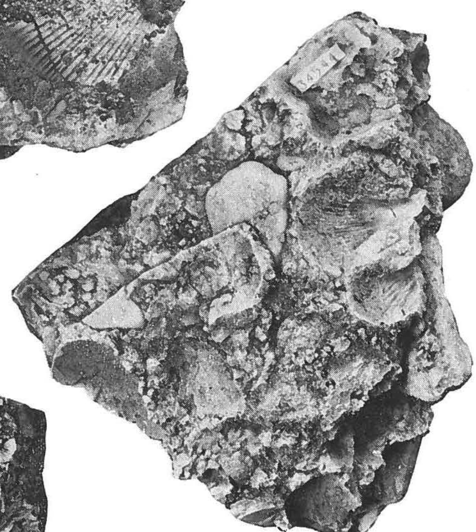

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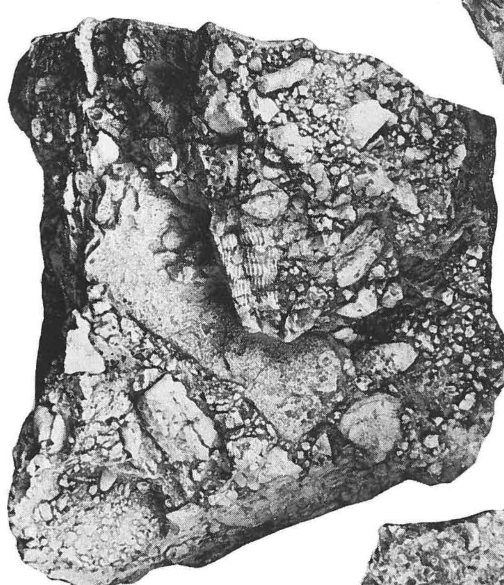

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Plate 8

Fig. 1. Conglomeratic arkose with fragment of fenestrate bryozoan. Triassic, unit 3, locality 13.75. ×1.5. MGUH 13,844.

Fig. 2. Conglomeratic arkose with fragments of bryozoans and brachiopods. Triassic, unit 3, locality 13.75. ×1. MGUH 13,845.

Fig. 3. Conglomeratic arkose with fragments of brachiopods. Triassic, unit 4, locality 14. ×1. MGUH 13,846.

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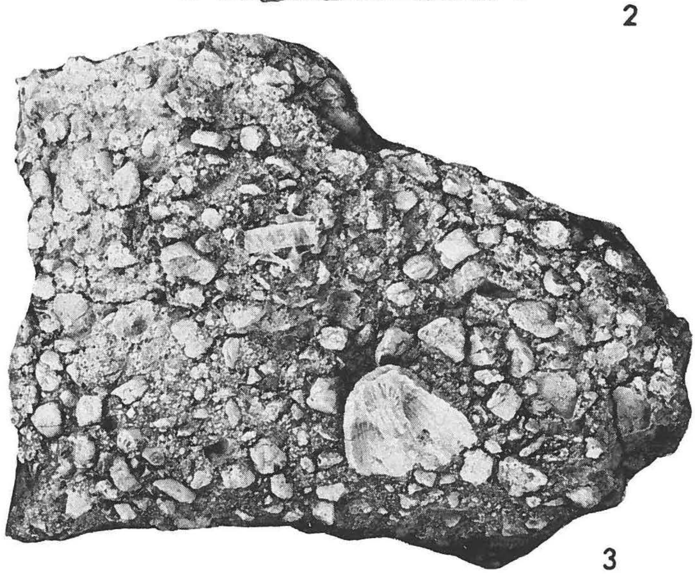

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Plate 9

Fig. 1. Conglomeratic arkose showing impressions of "mud ball" lined with fragments of bryozoans, originally attached to the surface of the mud ball. Triassic, unit 4, locality 14. ×1. (Field no. T67–98). MGUH 13,847.

Fig. 2. Conglomeratic arkose with *Spiriferella keilhavii* (von Buch). Triassic, unit 4, locality 14. ×1. MGUH 13,848.

Fig. 3. Conglomeratic arkose with fragments of brachiopods. Triassic, unit 4, locality 14. ×1. MGUH 13,849.

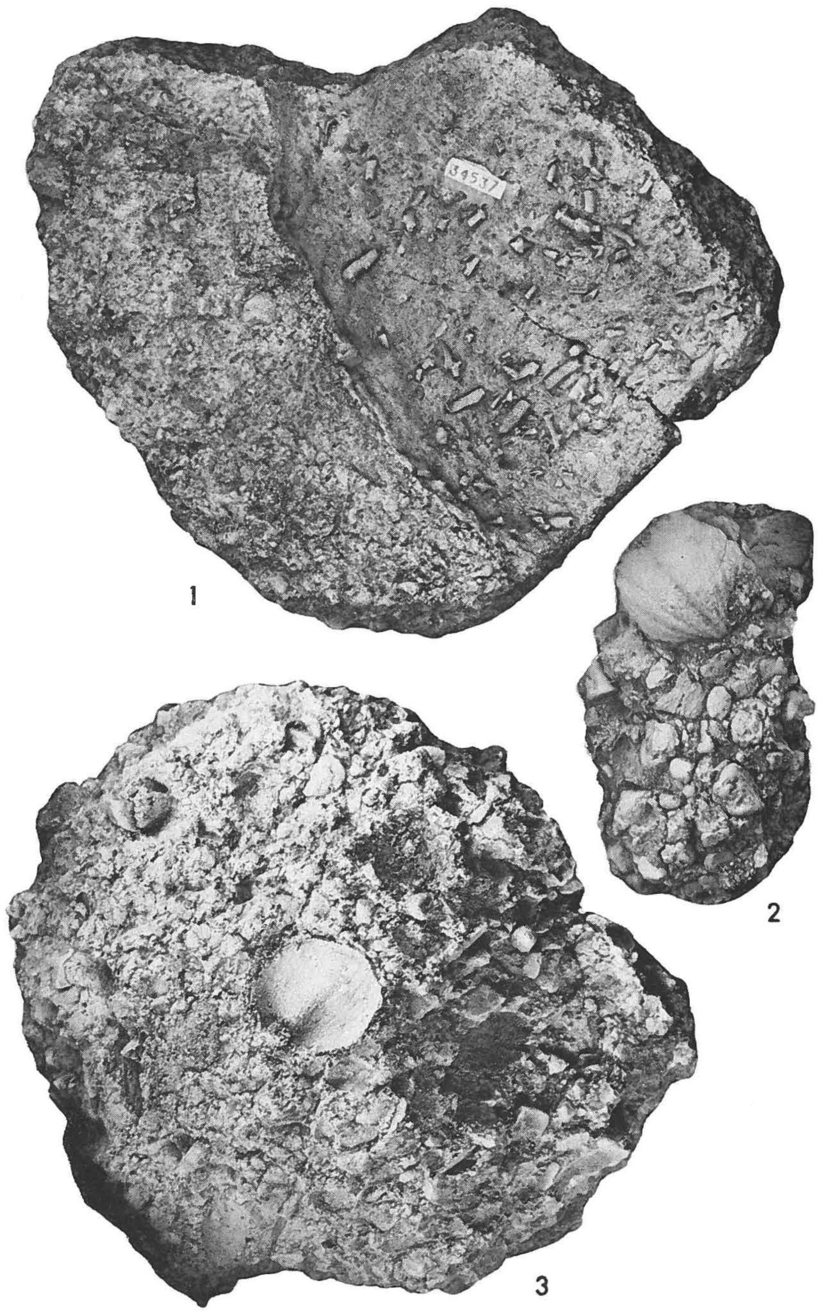
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Plate 10

Fig. 1. Conglomeratic arkose with ophiceratid ammonoid. Triassic, unit 4, locality 14. ×1. MGUH 13,850.

Fig. 2. *Otoceras woodwardi boreale* SPATH. Triassic, unit 16, locality 6.75. ×1. (Field no. T67–90). MGUH 13,851.

Fig. 3. *Otoceras woodwardi boreale* SPATH. Triassic, unit 16, locality 6.75. ×1. (Field no. T67–90). MGUH 13,852.

Fig. 4. Ventral valve of *Kochiproductus plexicostatus* DUNBAR. Triassic, unit 4, locality 14. ×1. MGUH 13,853.

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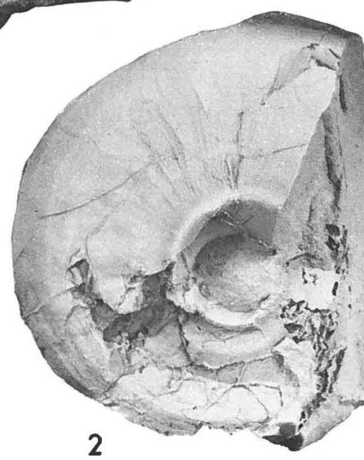

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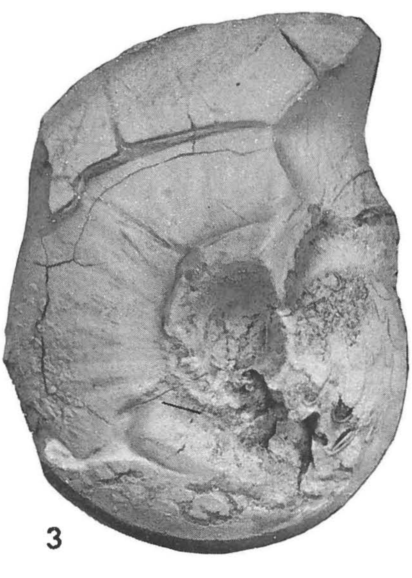

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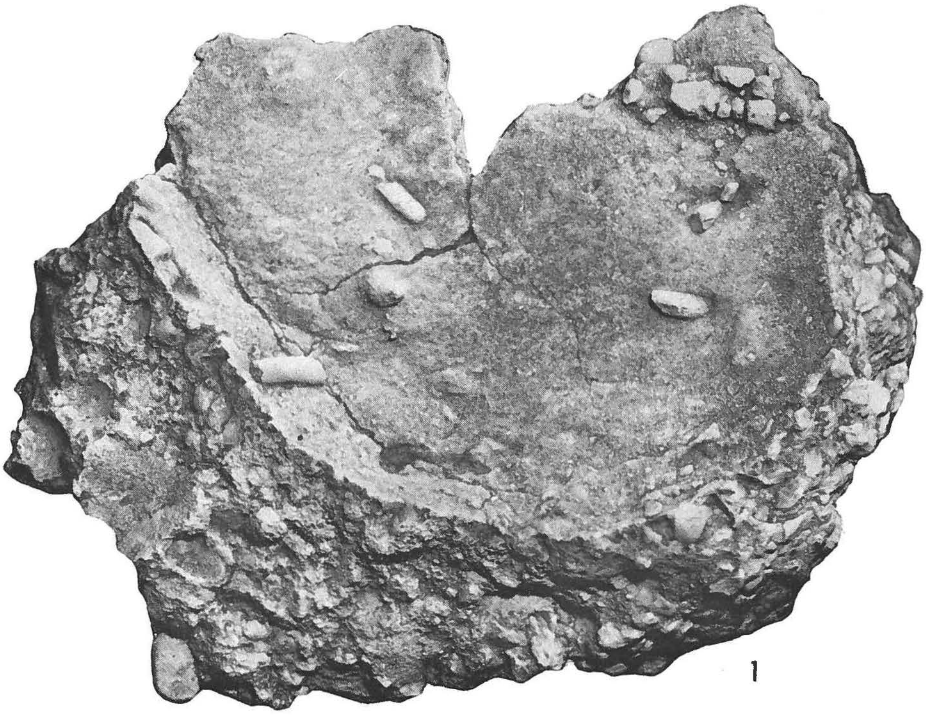
Plate 11

Fig. 1. Conglomeratic arkose showing impressions of mud ball lined with fragments of Bryozoa. Triassic, unit 3, locality 13.75. ×1. MGUH 13,854.

Fig. 2. Conglomeratic arkose showing impressions of mud ball lined with fragments of Bryozoa. Triassic, unit 4, locality 14. ×1. (Field no. T67–98). MGUH 13,855.



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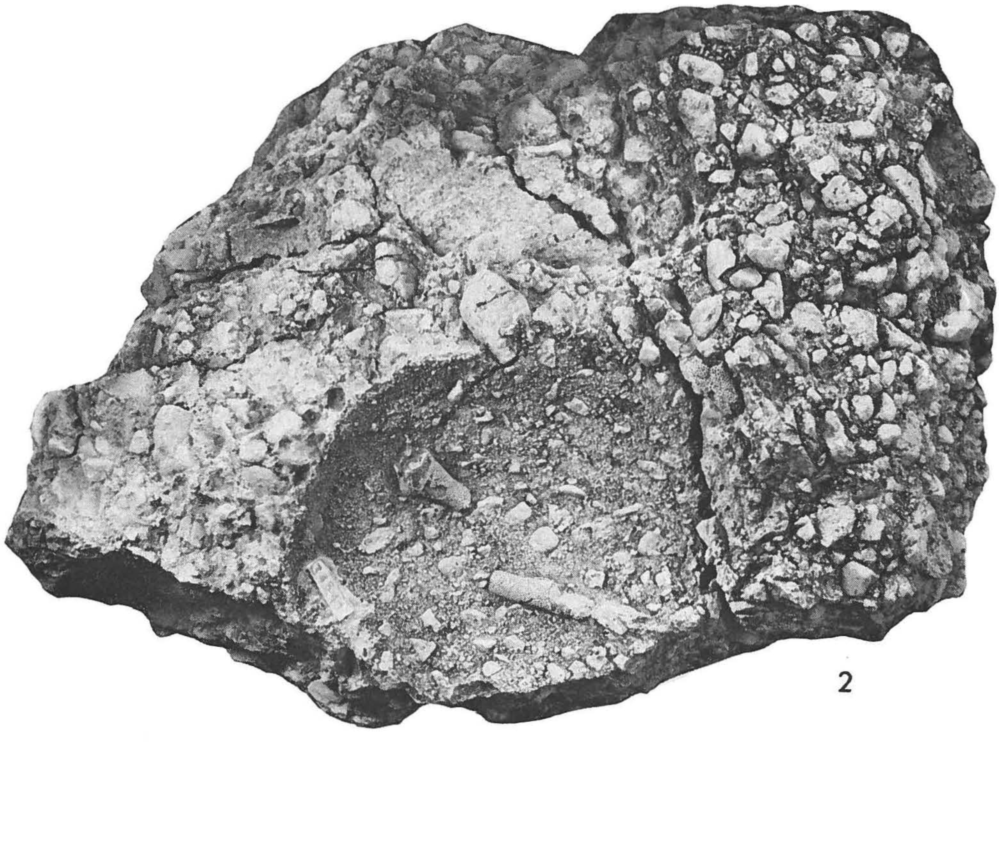

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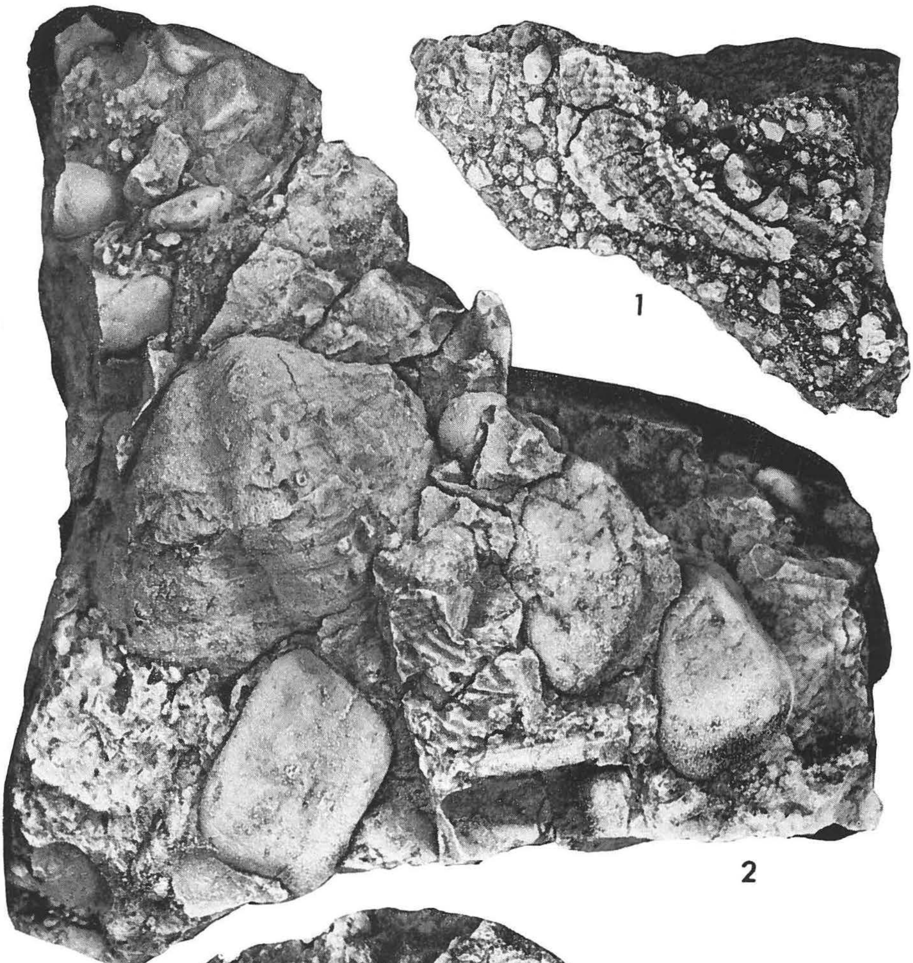
Plate 12

Fig. 1. Conglomeratic arkose with large fragments of brachiopod. Triassic, unit 4, locality 14. ×1. (Field no. T67–98). MGUH 13,856.

Fig. 2. Coarse conglomeratic arkose with large specimens of ?*Pleurohorridonia* sp. and small fragments of brachiopods. Triassic, unit 3, locality 13.75. ×1. MGUH 13,857.

Fig. 3. Conglomeratic arkose with interior dorsal valve of *Muirwoodia greenlandica* DUNBAR. Triassic, unit 4, locality 14. ×1. (Field no. T67–98). MGUH 13,858.



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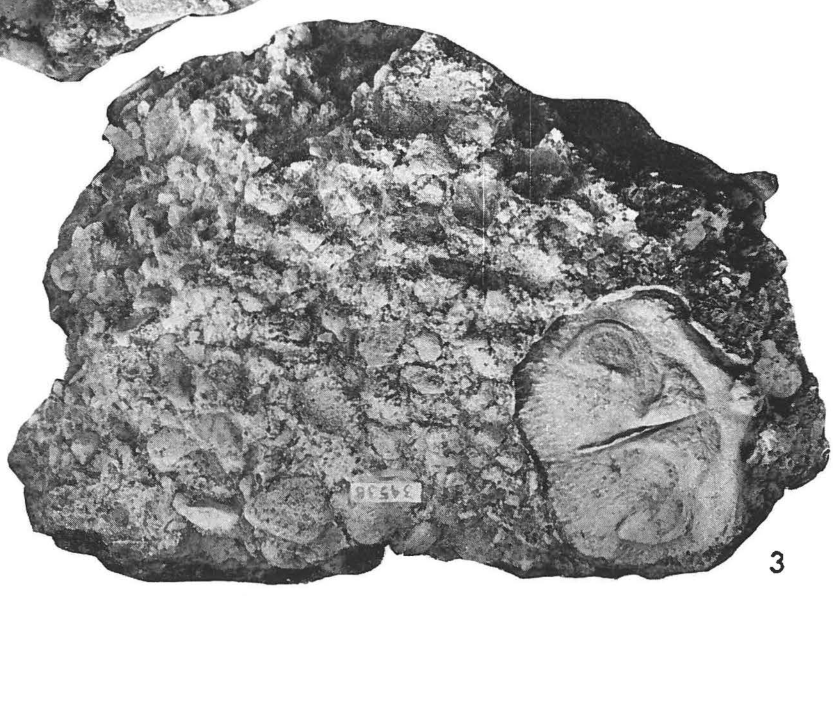

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Plate 13

Fig. 1. *Otoceras woodwardi boreale* SPATH, Triassic, unit 4, locality 14. ×1. MGUH 13,859.

Fig. 2. Conglomeratic arkose with fragment of *Otoceras woodwardi boreale* SPATH. Triassic, unit 4, locality 14. ×1. MGUH 13,860.

Fig. 3. Conglomeratic arkose with indeterminate ammonoid (*Ophiceras*?). Triassic, unit 4, locality 14. ×1. MGUH 13,861.

Fig. 4. Indeterminate ammonoid (*Ophiceras*?). Triassic, unit 4, locality 14. ×1. MGUH 13,862.

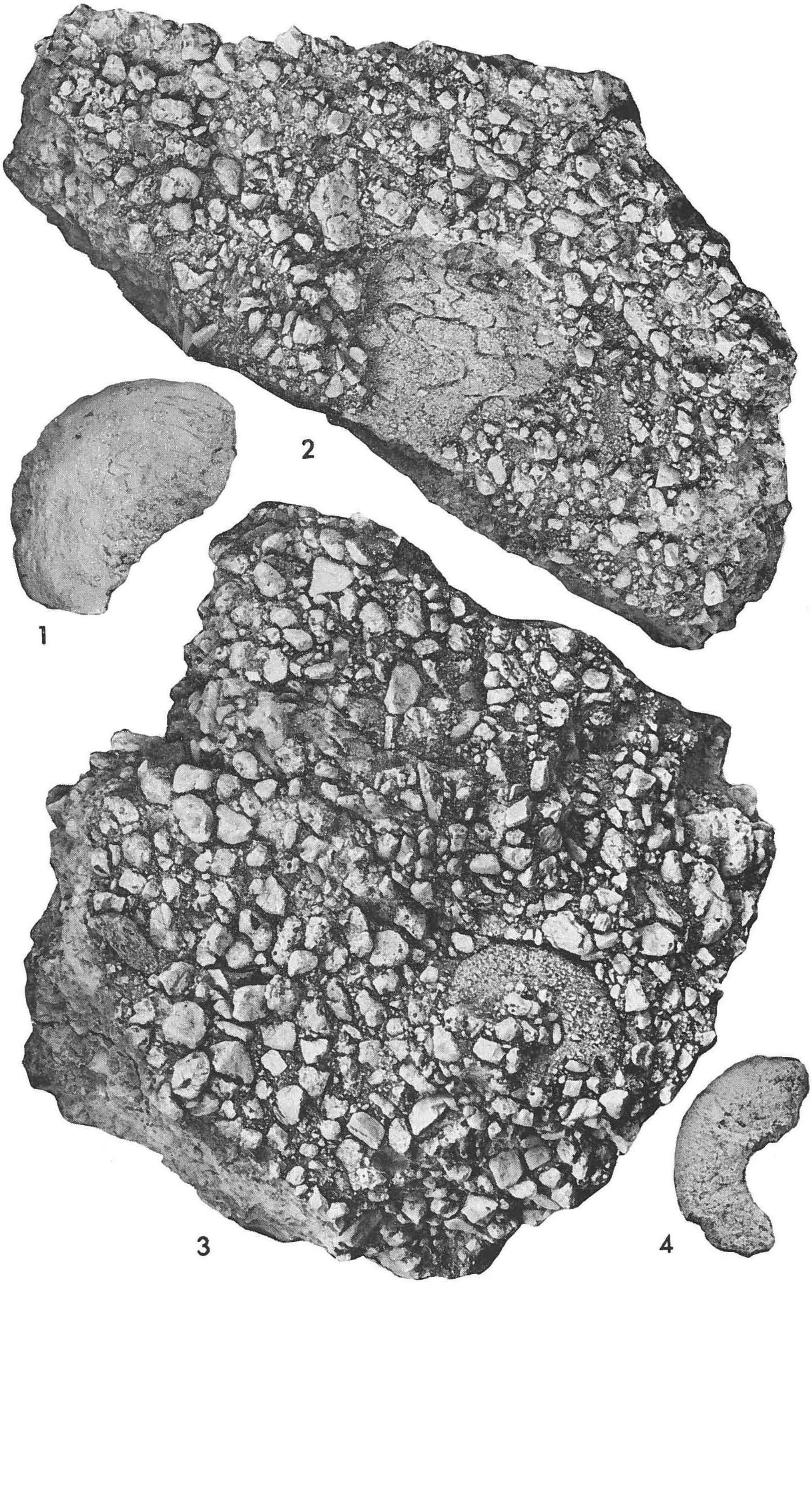
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Plate 14

Photomicrographs of Permian and Triassic rocks from Kap Stosch area. All figures ×32.

Fig. 1. Echinoid spine and bryozoan fragment in arenaceous limestone. Upper 30 cm of *Productus* limestone, uppermost Permian, Loc. 2, unit 7. (Field no. T67–83). MGUH 13,863.

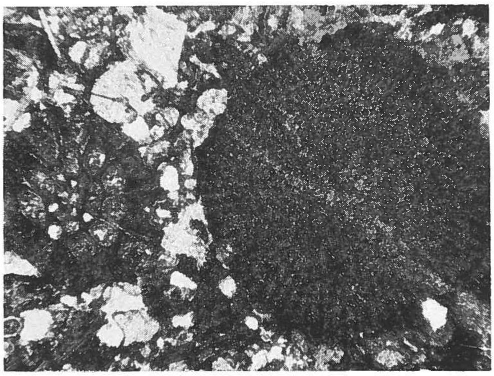
Fig. 2. Fenestrate bryozoan fragment in calcareous sandstone. Float block, either Permian or Triassic, 20 m above river bed, south side of River Zero. (Field no. O–X). MGUH 13,864.

Fig. 3. Echinoid spine and bryozoan fragment in calcareous sandstone. Float block, basal Triassic, top of south bank of River Zero, 45 m above river bed. (Field no. 0–10c). MGUH 13,865.

Fig. 4. Coral fragments in calcareous sandstone. Float block, either Permian or Triassic. Same locality as Figure 2 above. (Field no. T67–92). MGUH 13,866.

Fig. 5. Broken bryozoan fragment in calcareous sandstone. Basal Triassic, same locality as Figure 3 above. (Field no. 0–10b). MGUH 13,867.

Fig. 6. Phylloid algae in argillaceous matrix. Basal Triassic, float block in Loc. 1, unit 9 (possibly derived from somewhat higher beds). (Field no. T67–65). MGUH 13,868.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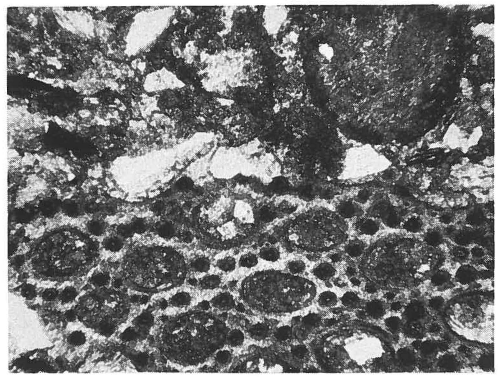
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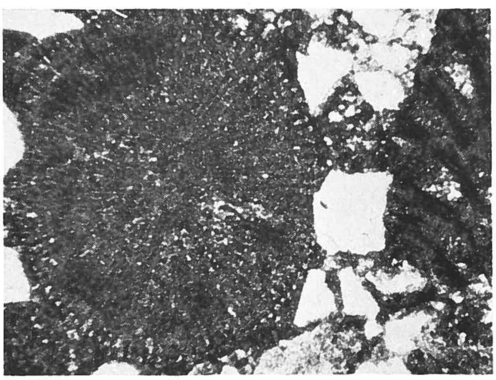
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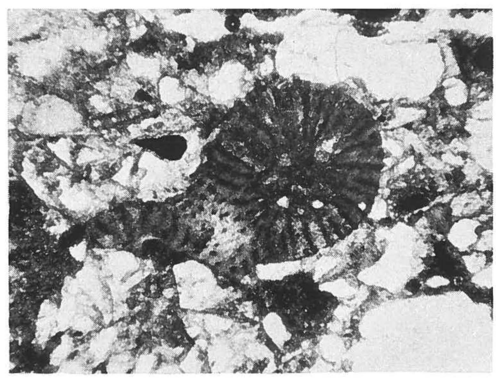
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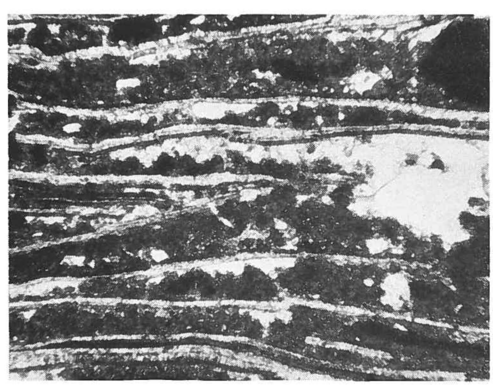
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Plate 15

Photomicrographs of Triassic rocks from Kap Stosch area. All figures ×32.

Fig. 1. Stromatolitic algae and siltstone clasts. Probably basal Triassic (immediately below bed with *Otoceras*), Loc. 1, unit 5. (Field no. 1–5). MGUH 13,869.

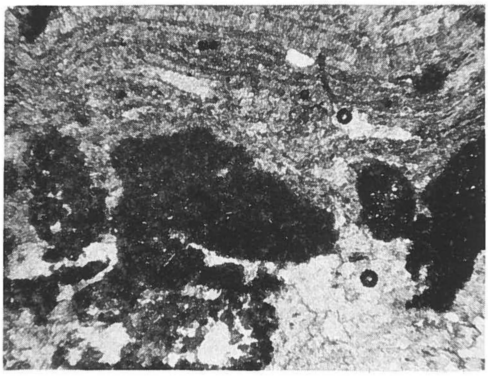
Fig. 2. Phylloid algae in argillaceous limestone. Early Triassic, (Loc. 2.1, unit 1), not less than 10 m above base of Triassic section. (Field no. 2.10–31). MGUH 13,870.

Fig. 3. Trepostomatous bryozoan fragment, productid spines, and other fossil "hash". 90–100 m base of Triassic section, bed containing productids, *Otoceras*, and *Glyptophiceras*, Loc. 6.75, unit 16. (Field no. 6. 75–16). MGUH 13,871A.

Fig. 4. Same rock as Figure 3, with endothyracean foraminifer (*Colaniella*?). MGUH 13,871B.

Fig. 5. Quartz grains in arkosic sandstone (note fractures in large grain which is complexly composite). Basal Triassic, Loc. 13.75, unit 4. (Field no. 13. 75–4). MGUH 13,872.

Fig. 6. Fossil "hash" of bryozoan and brachiopod debris, with echinoid spine and algal laminae traversing the picture. Basal Triassic, float not more than 12 m above top of Permian (*Martinia* limestone), halfway between Rivers 13 and 14. (Field no. T67–102). MGUH 13,873.



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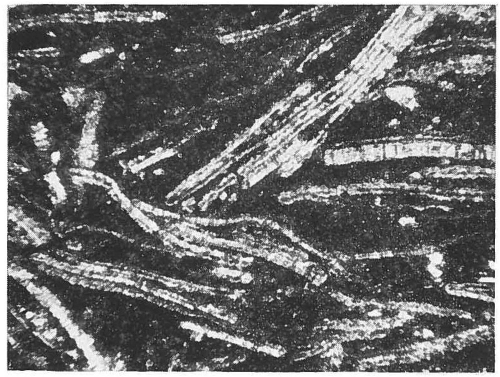

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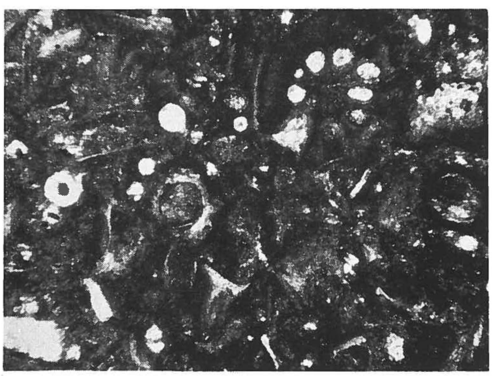

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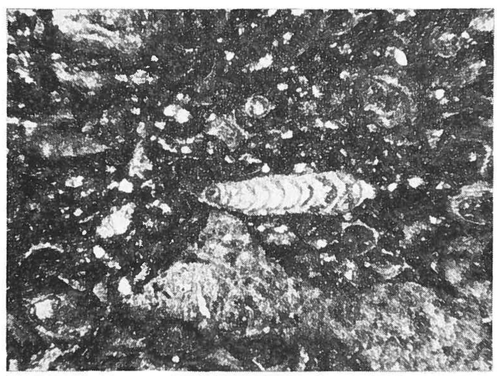

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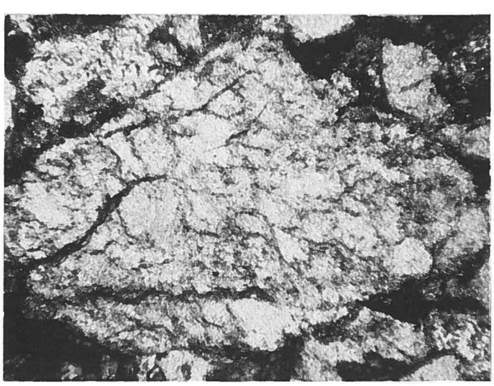

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Plate 16

All figures are scanning electron micrographs. All specimens are mounted on one stub, which bears the catalog designation OSU 29520 and is housed in the Orton Museum of Geology, The Ohio State University, Columbus, Ohio, 43210 U.S..

Fig. 1. *Ellisonia gradata* SWEET, 1970. Lc-element, ×140. From sample 68KG–1. MGUH 13,874.

Fig. 2. *Ellisonia gradata* SWEET, 1970. U-element, viewed obliquely from the posterior, ×140. From sample 68KG–1. MGUH 13,875.

Fig. 3. *Ellisonia gradata* SWEET, 1970. LB2-element, lateral view, ×140. From sample 68KG–1. MGUH 13,876.

Fig. 4. *Ellisonia gradata* SWEET, 1970. U-element, lateral view, ×140. From sample 68KG–1. MGUH 13,877.

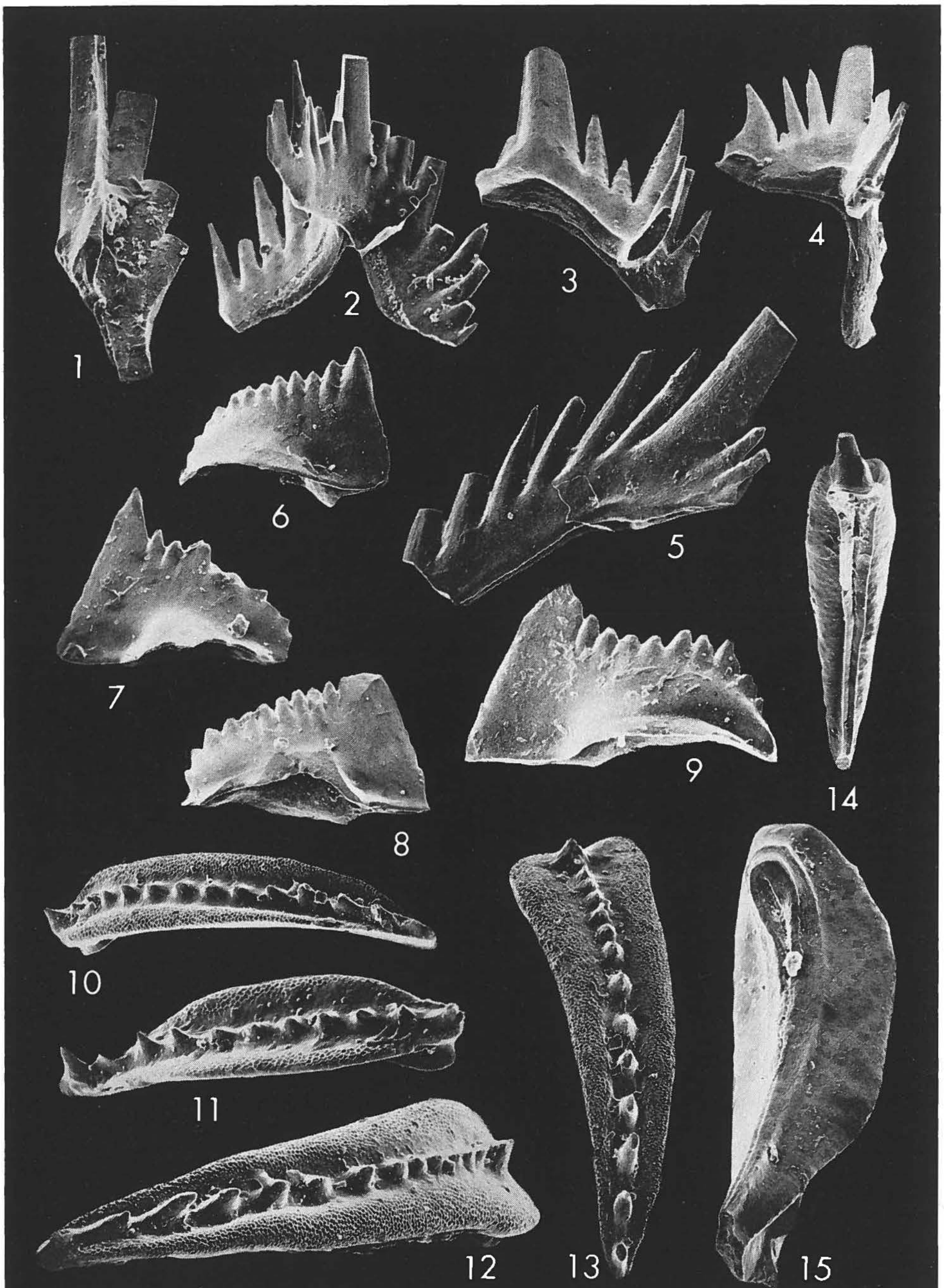
Fig. 5. *Xaniognathus* sp. Lateral view, ×125. From sample 68KG–1. MGUH 13,878.

Figs. 6, 7, 8. *Anchignathodus typicalis* SWEET, 1970. Lateral views of three representative specimens, all ×65. From sample 68KC–33. MGUH 13,879–13,881, respectively.

Fig. 9. ?*Anchignathodus typicalis* SWEET, 1970. Lateral view of a large specimen with a sinuous denticle profile that is not typical of *A. typicalis* but reminiscent of *A. julfensis* SWEET, 1973, ×65. From sample 68KB–1. MGUH 13,882.

Figs. 10–13. *Neogondolella rosenkrantzi* (BENDER & STOPPEL, 1965). Oblique lateral and upper views of four specimens representing different growth stages, ×70, 110, 75, and 60 respectively. From sample 68KK–1. MGUH 13,883–13,886, respectively.

Figs. 14, 15. *Neogondolella carinata* (CLARK, 1959). Views of the under sides of two specimens representing early and later growth stages, ×82 and 108 respectively. From sample 68KG–1. MGUH 13,887, and 13,888, respectively.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