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By Michael Churkin, Jr., *and* Claire Carter

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Geology and paleontology of three newly named Paleozoic formations and descriptions of six new graptolites

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Stratigraphy, Structure, And Graptolites of an Ordovician and Silurian Sequence in the Terra Cotta Mountains, Alaska Range, Alaska

By Michael Churkin, Jr.[1], *and* Claire Carter[2]

ABSTRACT

A heretofore essentially undescribed, tripartite Paleozoic sequence of graptolite-rich argillaceous rocks, quartzo-feldspathic sandstone, and limestone of the Dillinger terrane forms the Terra Cotta Mountains south of the Denali-Farewell Fault System in south-central Alaska. The lower part of the stratigraphic sequence consists of interbedded shale, siltstone, mudstone, and limestone, herein named the Post River Formation. This formation is further subdivided into (ascending) the lower siltstone member, mudstone member, upper siltstone member, Graptolite Canyon Member, and limestone member. Graptolites from this formation represent 15 graptolite zones ranging in age from the Early Ordovician (Tremadocian) into the Early Silurian (Llandoverian). The Post River Formation is overlain by a sequence of rhythmically interbedded sandstone, mudstone, and minor limestone herein named the Terra Cotta Mountains Sandstone. These rocks are generally coarser grained than clastic strata higher and lower in the section and have prominent graded bedding and sole markings characteristic of turbidites. Three major limestone members within the formation are mapped separately. Four graptolite zones of late Early Silurian (Wenlockian) age have been recognized in the formation, and an additional fauna of Late Silurian (Ludlovian) age spanning several zones was also recognized. Overlying these two predominantly siliciclastic formations is a thick sequence of laminated limestone and dolomite herein named the Barren Ridge Limestone. This formation consists of two relatively pure carbonate members separated by a calcareous siltstone and sandy limestone member. The Barren Ridge Limestone is unfossiliferous and is provisionally assigned a Devonian(?) age.

A nearly complete succession of graptolite faunas is precisely tied to the about 1,000-m sequence of map units detailed above. Together they serve both as an important biostratigraphic reference section for Alaska and as a detailed succession of map units for structural analysis.

The main structural feature of the Terra Cotta Mountains is the large north-trending overturned Terra Cotta Anticline that parallels the western front of these mountains. The Dillinger terrane extends northwestward about 32 more kilometers and is juxtaposed against the Nixon Fork terrane across the Farewell Fault. Most of the exposed rocks of the Dillinger terrane consist of the Terra Cotta Mountains Sandstone. The graptolitic shales of the underlying Post River Formation are exposed in only a few narrow anticlines that show no sign of underlying rigid basement rocks. The Dillinger terrane appears to be a highly deformed (>50 percent shortening) allochthon that is detached from its basement. The tripartite stratigraphic succession within the Dillinger terrane is found nowhere else in Alaska, but it has similarities to sequences in the Selwyn Basin of northwestern Canada.

Graptolite faunas found in the Post River Formation and the Terra Cotta Mountains Sandstone represent 9 Ordovician and more than 10 Silurian graptolite zones. These faunas have been correlated with similar faunas from Canada, New Zealand, Great Britain, Idaho, and Texas. Of the 95 species described and illustrated, 2 are new species, *Pleurograptus collatus* and *Monograptus digitatus*, 2 are new subspecies, *M. digitatus digitatus* and *M. digitatus subdigitatus*, and 3 are unnamed new species.

INTRODUCTION

This two-part paper describes in detail the stratigraphy, structure, and graptolites of a heretofore essentially undescribed Paleozoic sequence in the Terra Cotta Mountains of the central Alaska Range. The first part describes the succession of Lower Ordovician through Early Silurian graptolite-rich argillaceous rocks overlain by a Silurian section of quartzo-feldspathic sandstone and shale that is, in turn, overlain by a thick succession of limestone of Devonian(?) age. This tripartite stratigraphic succession is unique in Alaska; with its rich graptolite faunas, it provides an important reference section in south-central Alaska that can be used to map and reconstruct the stratigraphic, structural, and tectonic framework of a much larger part of interior Alaska. The second part of the report describes and illustrates the succession of stratigraphically well controlled graptolite faunas that constitutes one of the most complete Ordovician through Early

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Silurian graptolite-zone reference sections in the northern cordillera.

The location of the area of study is shown in figure 1. The Terra Cotta Mountains consist of a north-south trending range of mountains on the north side of a small part of the central Alaska Range about 160 km southwest of Mount McKinley. The South Fork of the Kuskokwim River defines the east edge of the Terra Cotta Mountains, and the Post River runs along the west side of the mountains. The Terra Cotta Mountains range in elevation from 600 to 1,500 m and consist of barren crags and cliffs separated by more-gentle talus slopes whose terra cotta color (reddish brown) gives the mountains their name. There are no permanent snow fields or glaciers here, but large granite erratics that are scattered throughout the mountains indicate that glaciers once covered the mountains. The area is remote, and there are no roads. Access is by helicopter or small fixed-wing aircraft able to land on the gravel bars of the Kuskokwim and Post Rivers. The most convenient access is by helicopter from Farewell Lake Lodge on Lake Farewell, about 35 km north of the main part of the Terra Cotta Mountains. A short gravel airstrip next to Rohn Roadhouse is not regularly maintained.

PREVIOUS STUDIES

In 1898, J.E. Spurr and W.S. Post of the U.S. Geological Survey (USGS) ascended the Skwentna River, crossed the Alaska Range, and descended the Kuskokwim River in canoes. This was the first party to cross the Alaska Range and to describe the general features of the geography and geology of the area (Spurr, 1900). The following year, a party of 8 men and 15 horses, commanded by Lt. J.S. Herron, crossed the Alaska Range by way of Simpson Pass and also descended the Kuskokwim, but they made no geological observations.

Spurr (1900, p.51) named the Terra Cotta Mountains for their "superb and peculiar coloring." He determined, mainly by examining "pebbles from [the] bases" of the mountains, that they were formed of "heavy-bedded impure limestones, slates and arkoses, with probably some volcanic rocks." He named these rocks the Terra Cotta series and surmised that they were probably of Jurassic age. He also noted that they were cut by numerous dikes of intrusive rocks.

In 1902, A.H. Brooks led an 8-man, 20-horse USGS expedition over nearly the same route (Brooks, 1911) to the west side of the Alaska Range. Brooks did not examine the mountains west of the Kuskokwim River, but extrapolated that they were composed of the same rocks as the mountains to the east. These rocks were called the Tatina group and consisted of limestones interbedded with argillites and calcareous slates. The Tatina group in the Terra Cotta Mountains was believed to be intruded by diabase dikes. A member of the party, L.M. Prindle, discovered graptolites in float along some tributaries of the Dillinger River, and these were ascribed to rocks of the Tatina group. Charles Schuchert identified the graptolites as *Climacograptus bicornis* (Hall), *C.* sp., and *Dicranograptus* cf. *ramosus* (Hall) (Brooks, 1911).

The next geologic studies in the region took place in 1967 when Bruce Reed, who discovered graptolites in the Terra Cotta Mountains, started a series of investigations that led to the delineation of mineralization in the area (Reed and Elliot, 1968a; 1968b). At the same time, the first report on the area was published by the Alaska Division of Mines and Minerals (Herreid, 1968). During the studies by Bruce Reed and his associates, who included Raymond Elliot and Rod May, graptolites were found in the Terra Cotta Mountains. Many of the first collections were made by Rod May. In 1969, at Reed's invitation, Michael Churkin, then employed by the USGS, and William Kerr, then of the Canadian Geological Survey, established Camp #1 by helicopter, near the crest of the Terra Cotta Mountains (pl. 2). From this single-tent camp and another one several kilometers to the south (Camp #2, pl. 2), daily foot traverses over the next 8 days established that a remarkably complete and well-exposed graptolitic succession was present along the crest and western slope of the Terra Cotta Mountains. Subsequent work consisted of foot traverses by Churkin and May from two spike camps (Camp #1 1970 and Camp #2 1970; pl. 2). The 1970 work expanded knowledge of the stratigraphy into the sandstones and carbonate rocks that lie higher in the section farther to the east. In 1976, the area was revisited by Churkin and Gary Winkler, who further expanded the earlier mapping. During this time, Winkler examined the interbedded sandstone and shale section and made numerous sedimentological observations, measurements of paleocurrent directions, and interpretations of sedimentary environments. In 1977, a preliminary description of the stratigraphic succession was published (Churkin, Reed, and others, 1977) but no new formational names were designated, and the faunal succession and its correlation were only outlined.

In 1977, members of the Alaska Division of Geological and Geophysical Surveys (ADGGS) started systematic geologic mapping of the area. Work by ADGGS has resulted in the publication of detailed geologic maps (scales 1:63,360 and 1:40,000) covering an area of about 2,500 square km in the vicinity of the Terra Cotta Mountains. These maps include the McGrath B-2 quadrangle (Bundtzen and others, 1982), the McGrath A-2 quadrangle (Bundtzen and others, 1987), the McGrath B-3 quadrangle (Gilbert and others, 1982), the McGrath A-3 quadrangle (Gilbert and Solie, 1983), and the McGrath C-1 quadrangle, which includes rocks in the Dillinger River drainage (Kline and others, 1986). Map units and their ages were not formalized in these ADGGS maps, either. The results of these field studies have been summarized by Bundtzen and Gilbert (1983).

Since 1967, Churkin has worked in neighboring terranes containing lower Paleozoic stratigraphic sequences that may or may not be related to the Terra Cotta sequences. These include, to the east, the chert, shale, and limestone sequences in the Lake Minchumina area (Churkin and others, 1980), the Livengood area (Chapman and others, 1980), and the Tatonduk area (Churkin and Brabb, 1968) and, 125 km to the southwest near White Mountain (Churkin and Wesley K. Wallace, unpub. data, 1984), a graptolite shale, sandstone, and limestone tripartite sequence very much like that described here from the Terra Cotta Mountains (pl. 3*A*).

ACKNOWLEDGMENTS

The late Bruce Reed recognized the need and potential for stratigraphic and structural studies in the area, stimulated the authors to undertake the work, and provided logistical support. Rod May provided much assistance during the 1970 field season. The late Mike Estlund was a tireless support person who, together with Reed, helped resupply our spike

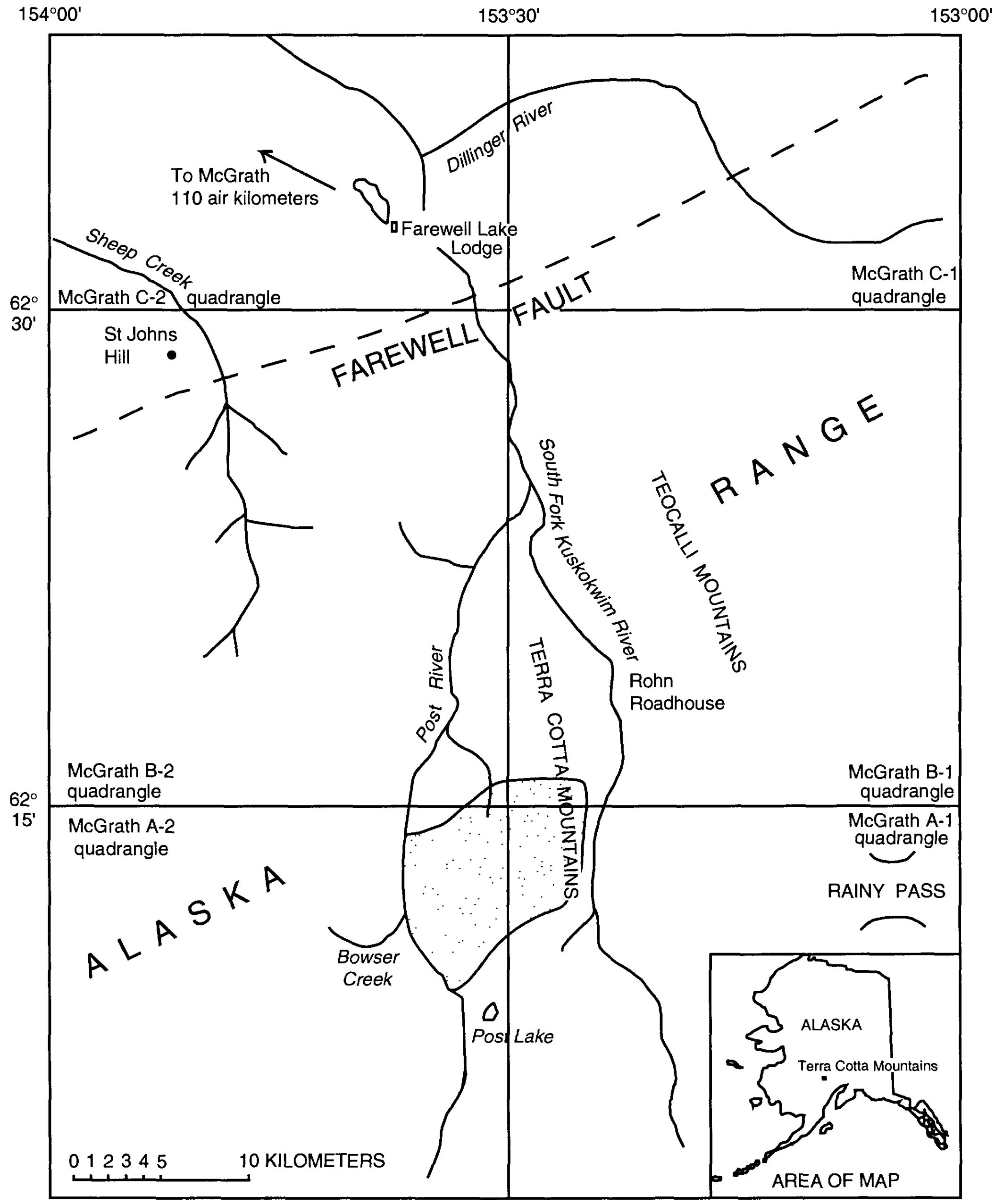


Figure 1. Index map showing location of Terra Cotta Mountains, Alaska. Area mapped in plate 1 is stippled.

camps and on numerous occasions air-dropped carefully wrapped supplies while Reed piloted the plane. William Kerr, then of the Canadian Geological Survey, enthusiastically shared in the original description of the stratigraphic succession and its imbricate structure and made numerous graptolite discoveries. Tom Bundtzen and Wyatt Gilbert kindly provided reports and maps and shared their knowledge of the area. Bruce Reed and Stanley Finney reviewed the manuscript, and their cogent comments and suggestions were most helpful. The warm hospitality and never-failing logistical support of Stan and Martha Frost, owners of the Farewell Lake Lodge, are gratefully acknowledged.

STRATIGRAPHY AND STRUCTURE OF A GRAPTOLITE-RICH ORDOVICIAN AND SILURIAN SEQUENCE IN THE TERRA COTTA MOUNTAINS

By Michael Churkin, Jr., and Claire Carter

REGIONAL GEOLOGIC SETTING

The Terra Cotta Mountains form part of a mosaic of Paleozoic terranes making up the Alaska Range (Jones and others, 1982) and parts of east-central Alaska (Churkin and others, 1984). The sequence of highly deformed and thrust-faulted shale, mudstone, sandstone, and limestone ranging in age from Ordovician through Devonian (Churkin, Reed, and others, 1977) has been assigned to the Dillinger terrane (Bundtzen and Gilbert, 1983; Churkin and others, 1984), named for the Dillinger River in the vicinity of Schellabarger Pass (Jones and others, 1982), but the stratigraphic succession in Schellabarger Pass is far less well known (Armstrong and others, 1977) and appears to be less complete.

The Farewell Fault, which lies along the north flank of the Alaska Range, is a western extension of the Denali Fault. It separates mainly siliceous and calciclastic rocks of early Paleozoic age (Dillinger terrane) on the south from the mainly limestone and dolomite sequence of middle Paleozoic age (Nixon Fork terrane), including shelly-fossil-rich reef-related deposits at St. John Hill to the north (Bundtzen and others, 1982). About 125 km to the west in the White Mountain Mine area, in a similar relationship, carbonate rocks of the Nixon Fork terrane have also been found along the north side of the Farewell Fault against graptolitic, argillaceous, and sandy rocks to the south (Churkin and W.K. Wallace, unpub. data, 1984). Much younger but also highly deformed Jurassic and Cretaceous flysch rocks, volcanic rocks, and plutonic rocks occur on the south and west sides of the Terra Cotta Mountains (Bundtzen and Gilbert, 1983). The rocks of the darker colored sequence of Mesozoic flysch (Kahiltna terrane) are faulted against the Paleozoic strata that form the Terra Cotta Mountains (Bundtzen and others, 1987).

The structure of the Terra Cotta Mountains consists of a series of north-trending isoclinal and chevron folds overturned to the west. The fold limbs and axial planes dip about 35° to the east and are cut by many nearly parallel thrust faults. In general, the thrust faults appear to be subparallel to the bedding and do not exhibit very much stratigraphic throw. In places, small cross faults are perpendicular to the fold axes. These east-west faults are particularly noticeable in the Post River Formation where they displace the contact between the lower siltstone member and the overlying mudstone member along the west flank of the mountains. The base of the section is not known, and the oldest unit, containing Early Ordovician graptolites, is exposed in the large overturned Terra Cotta Anticline (Bundtzen and others, 1987), along the west side of the Terra Cotta Mountains (pl. 1). Despite penetrative deformation in the argillaceous lithologies, the rocks are not obviously metamorphosed, and graptolites, as well as fine details of sedimentological layering, are very well preserved. Most of the graptolites are not appreciably tectonically deformed. Slaty cleavage parallel to the axial planes of folds is very well developed in the finer grained argillaceous members of each formation. In fact, many of the argillaceous surfaces, especially in the lower part of the section, have a shiny appearance and appear phyllitic. In thin section there is much evidence of recrystallization of clays and the development of small crystals of secondary mica. Graptolites are most easily found where cleavage parallels the bedding, especially on the limbs of folds. In the axial regions of folds, graptolites are difficult to find because the bedding planes are closely intersected by cleavage. The Graptolite Canyon Member of the Post River Formation, however, is generally so fossiliferous that despite places where cleavage has obscured most of the graptolites, a careful search for uncleaved bedding planes usually yields a sufficiently well preserved fauna for determination of the age of the beds and their position in the section.

Igneous intrusions in the area include dikes, sills, and a few small stocks of both mafic and felsic composition. The mafic dikes are generally basaltic to gabbroic and are dark greenish gray. They are porphyritic in places, with euhedral plagioclase, and they weather orange-brown. According to Bundtzen and others (1987), these igneous intrusions are early Tertiary in age. However, there are some dark green greenstone sills or flows within the lowest member of the Post River Formation that, on the basis of deformation style and alteration, may be of Paleozoic age (Bundtzen and others, 1987).

STRATIGRAPHIC SUCCESSION

The stratigraphic succession in the Terra Cotta Mountains is divided here into three new formations. At the base of the succession is the Post River Formation, composed of two members of calcareous siltstone separated by a mudstone member in its lower third, a thick, dark-gray, graptolitic shale member, and a limestone member at the very top. The Post River Formation is overlain by a rhythmically interbedded sandstone, mudstone, and limestone formation named the Terra Cotta Mountains Sandstone. Overlying these two units is a thick formation of laminated limestone, siltstone, and dolomite named the Barren Ridge Limestone (fig. 2).

POST RIVER FORMATION

The type section of the Lower Ordovician to Lower Silurian Post River Formation (pl. 2, section 1), named for the Post River, lies near the center of sec. 7, T. 24 N., R. 23 W. in the southeastern part of the McGrath 1:250,000 quadrangle. This section was measured from west to east up a steep canyon near the summit of the southwestern part of the Terra Cotta Mountains. More than 80 percent of the east-dipping section is exposed in the headwall of the canyon (fig. 3). The bottom of the section starts at 4,000 ft above sea level in thin-bedded, silty and argillaceous, crosslaminated, olive-gray limestone interbedded with micaceous siltstone (lower siltstone member, pl. 3*B*). Overlying these lighter gray beds is darker gray mudstone (mudstone member) with *Tetragraptus* sp. (see fig. 4 for sketches of key graptolite assemblages). This mudstone is overlain by an internally folded siltstone unit (upper siltstone member) that in turn is overlain by a thick dark-gray fissile shale with abundant graptolites that is named the Graptolite Canyon Member. Above the Graptolite Canyon Member is a small cliff exposure of dark-gray laminated limestone with shale partings (the limestone member of the Post River Formation). The contact with the overlying Terra Cotta Mountains Sandstone lies at about 5,000 ft elevation, in a narrow syncline along the drainage divide. The type section, not including the lowest member, is about 335 m (1,100 ft) thick. Minor faults cut the section, and locally some of the beds are internally isoclinally folded and cut by several dikes of intermediate composition. More than 40 stratigraphically separate graptolite collections were made along this measured section (pl. 2, sec. 1, and pl. 3*B*). Because of its unusually continuous exposure and its abundant graptolites, this section provides one of the most complete and best exposed successions of graptolite zones in the northern cordillera, surpassing those of the Road River Formation in east-central Alaska (Churkin and Brabb, 1965), the Descon Formation in southeastern Alaska (Churkin and Carter, 1970), and various other graptolite shale successions in the northern Canadian Cordillera (Lenz and Chen, 1985; Lenz and Jackson, 1986).

A reference section of the Post River Formation (section 2 on pl. 2 in secs. 32, 33, T. 25 N., R. 23 W.) is exposed 3.6 km north along strike from the type section. Here, an east-dipping section attenuated by thrust faults in its lower part runs along a small creek and adjacent ridge crest (peak 5310; pl. 2), forming the east limb of the same large, overturned anticline (Terra Cotta Anticline of Bundtzen and others, 1987). The top of the section here, as in the type section, ends in the Terra Cotta Mountains Sandstone in another small syncline. The relative positions of twelve separate graptolite horizons collected along this reference section are shown on structure section *A-B-C-D* of plate 1.

Other sections of the Post River Formation that reveal its lithologic and faunal successions are exposed along the upper reaches of Graptolite Canyon, which is a relatively large southwest-trending canyon (pl. 2) named for the very numerous graptolites occurring in shale talus along the creek banks (colln. site 70ACn292). Reference sections for the Graptolite Canyon Member include collection site 70ACn292 (pl. 2) in the headwaters area of Graptolite Canyon, a tributary canyon to Graptolite Canyon that runs from the mountain crest at Camp #2 1969 to past Camp #1 1970 (pl. 2), and a narrow canyon running southwest from Camp #1 1969 for about 1.6 km (pl. 2, reference section 3). This last section has good exposures and abundant fossiliferous horizons but is structurally very complex. More than a dozen graptolite collection sites along the section (colln. sites 69ACn411 to 69ACn461) indicate that the structure is an anticline overturned to the west (pl. 1).

LITHOLOGIC SUCCESSION AND MEMBERS

The Post River Formation consists mainly of fissile shale, mudstone, and silty and argillaceous limestone, and can be readily divided into five members (pls. 1,3*B*). At the base of the formation is the lower siltstone member, characterized by thin beds of crosslaminated calcareous siltstone and argillaceous limestone rhythmically interbedded with shale and argillite. Directly above the lower siltstone member is the relatively noncalcareous mudstone member, which is overlain by another calcareous siltstone and argillaceous interval, the upper siltstone member. The upper siltstone member is thinner than the lower siltstone member but otherwise closely resembles it lithologically. The overlying Graptolite Canyon Member is a nearly pure, darker gray shale and siliceous shale, with abundant graptolites, that forms most of the upper two-thirds of the formation. The uppermost part of the Post River Formation is the limestone member, a dark, laminated limestone interbedded with thin beds of black graptolitic shale.

LOWER SILTSTONE MEMBER

The lower siltstone member is a light-colored unit of medium-gray calcareous siltstone and silty limestone that is the basal part of the stratigraphic succession in the Terra Cotta Mountains. It is exposed along the west side of the mountains, where it forms the core of the Terra Cotta Anticline, a recumbent anticline overturned to the west. The base of the member is not exposed in the map area. The lowest known beds in the member are exposed in the steep, west-facing slopes along the Post River. The best exposures are along ridge crests where both limbs of the anticline are exposed. The ridge just south of the line of cross section *J-K* (pl. 1) is one of the better places to examine this member, which is more than 300 m thick here. Intense internal folding and shearing, however, make any accurate estimate of original thickness difficult. The lower siltstone member of the Post River Formation can be readily distinguished from all other rock units in the area with the exception of the much thinner (about 30 m thick) and stratigraphically higher upper siltstone member of the Post River Formation. Both the upper and lower siltstone members are characterized by very thin beds (mostly 2.5 to 15 cm) of calcareous siltstone and argillaceous limestone separated by thinner beds and partings of shale (fig. 5). The limey beds are strongly crosslaminated, and the sharply truncated tops of forset laminae provide clear indications of the tops of the beds. The shaly partings are generally altered to shiny films of sericite that give a phyllitic, olive-gray sheen to cleavage and bedding planes. Both the lower and upper siltstone members produce relatively nonresistant, smooth outcrops and large, shaly and platy talus slopes. Numerous platy slabs with uneven and crinkly bedding surfaces characterize these units. The rocks are medium gray with an olive tint, and they weather pale yellowish orange, in contrast to the much darker gray, purer shales higher up in the Post River Formation.

At collection site 70ACn501 (pl. 2; sec. 6, T. 24 N., R. 23 W.), some of the oldest beds known in the area are exposed. Thin beds of impure limestone form less than one-third of the section here, the remainder being sandstone, siltstone, and argillite containing rare, multibranched graptolites of the *Adelograptus* Zone (Early Ordovician; see table 1). Worm casts are abundant in some of the siltstone beds. Current markings and load casts produce lineations on the undersides of some of the limestone interbeds. Asymmetrical microfolds in silty limestone beds 2.5 to 5 cm thick have axial-plane cleavage. Thickened crests of the folds indicate some flowage. In this section, the siltstones contain quartz and feldspar (albite-twinned plagioclase) detritus together with detrital muscovite.

Along cutbanks of the Post River in the northwest corner of sec. 19, T. 24 N., R. 23 W., the contact of the lower siltstone member with the overlying mudstone member is intercalated over 3 m (pl. 2, colln. site 70ACn132). Here, medium-light-gray orange-weathering thin-bedded calcareous siltstone is interbedded with dark-gray *Tetragraptus*-bearing mudstone. The presence of another very similar unit of thin-bedded calcareous siltstone (upper siltstone member) about 75 m above the basal (lower) siltstone member also suggests a conformable and intercalated contact between the upper siltstone member and the Graptolite Canyon Member.

The age of the lower siltstone member is based on the presence of a few sparse graptolite faunas of the *Adelograptus* Zone. The member also has yielded specimens of the sessile, dendroid graptolite *Araneograptus*? preserved in

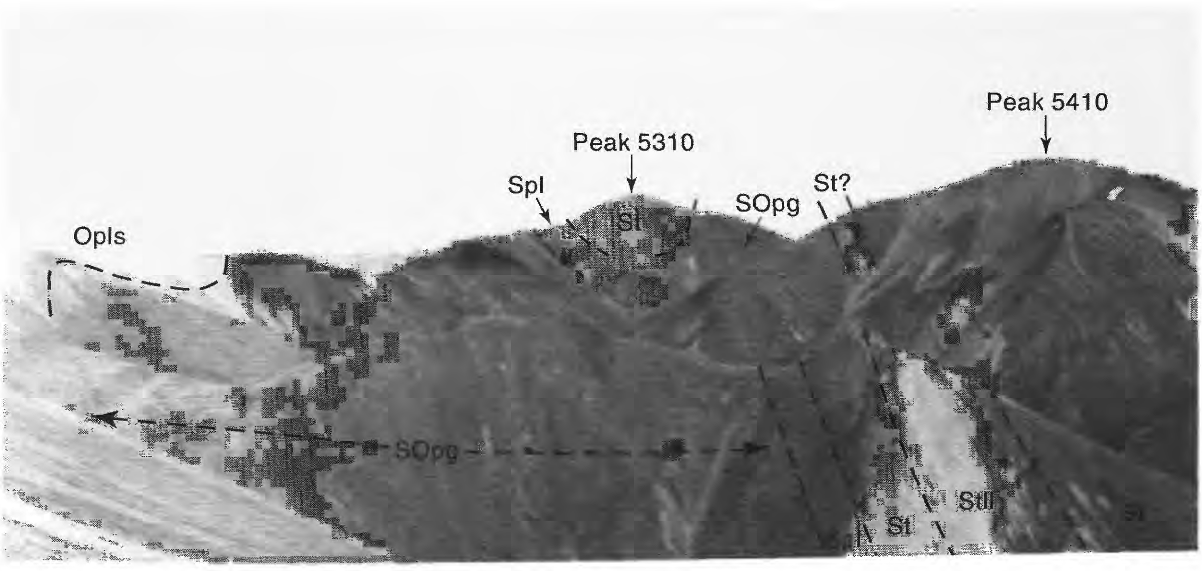


Figure 2. Panoramic view across Terra Cotta Mountains, south-central Alaska, showing general stratigraphy and structure in vicinity of Graptolite Canyon. View north from ridge crest south of Camp #1 1970 (pl. 2). Oldest units on left side of photograph (west) and youngest units on right (east). Note rock rubble that mantles steep slopes and obscures stratigraphic succession visible along ridge crests. Dark shale debris of the Graptolite Canyon Member (SOpg) of the Post River Formation covers lighter colored siltstone

semirelief on a light-gray phyllitic siltstone. During mapping, Churkin, Kerr, and Reed originally believed this fossil was Cambrian in age. Rocks in this unit could extend into the Cambrian (see Bundtzen and others, 1987).

MUDSTONE MEMBER

The mudstone member of the Post River Formation conformably overlies the lower siltstone member. The lithology of the mudstone member, together with its graptolite fauna, makes it a unique and easily recognizable unit within the area. The mudstone is a dark-gray, nonfissile, silt-rich argillaceous rock that splits into slabs parallel to bedding surfaces. These surfaces are rough, resembling fine sandpaper. Graptolites of the *Tetragraptus approximatus* and *T. fruticosus* Zones (Early Ordovician) occur in the member (table 1) and are frequently preserved in three dimensions as iron oxide minerals that have replaced pyrite molds. About 75 m of the mudstone member was measured in the type section of the Post River Formation, but cover, igneous intrusions (not shown on pl. 1), and possible faulting obscure the upper part of the member. The mudstone member is not differentiated on the western overturned limb of the Post River Anticline because this part of the area is largely cliffs and crags that cut into the lower siltstone member, and large scree piles obscure much of the structurally underlying mudstone. To the south (secs. 18, 19, T. 24 N., R. 23 W.), where the overturned western limb is exposed in river cuts of the Post River, the mudstone member contains *Tetragraptus* sp. Another place where the mudstone member probably occurs but has not been differentiated on the map is near Camp #1 1970 (pls. 1 and 2).

UPPER SILTSTONE MEMBER

The upper siltstone member conformably overlies the mudstone member. It consists of calcareous siltstone and argillaceous limestone that resemble the lower siltstone member, both in lithology and in bedding characteristics. The upper siltstone member is exposed mainly along the flanks of the syncline that forms the narrow drainage divide along the west side of the Terra Cotta Mountains east of the Post River. The member can be traced for about 6 km along strike on the west limb of the syncline but is present for only about 1.6 km on the east limb, where it appears to be either structurally duplicated near Camp #1 1970 (pls. 1 and 2) or cut out by faults further north. The repetition of the member near Camp #1 1970 suggests that bedding plane thrusts repeat the section there. As the member is only about 21 m thick, it may also be present where it could be largely obscured by large talus piles, particularly along the west overturned limb of the Terra Cotta Anticline. In both the type section of the Post River Formation and reference section 2 above Camp #1 1969, the upper siltstone member is more structurally deformed than the beds above it and below it. In both the type and reference sections, it is isoclinally folded and faulted. This folded structure may be related to the feldspar porphyry dikes that are closely associated with the upper siltstone member in both sections.

member (Opls) on far left. Dark sandstone- and mudstone-debris-covered slopes of the Terra Cotta Mountains Sandstone (undivided, St) are covered by light-colored limestone scree of the lower limestone member (Stll). Stml, Terra Cotta Mountains Sandstone, middle limestone member; Dbul, Dbs, Dbll, Barren Ridge Limestone (upper limestone, siltstone, and lower limestone members, respectively); Spl, Post River Formation, limestone member.

Well-developed crosslamination and the rhythmic interbedding of mudstone and impure limestone distinguish this member from the overlying Graptolite Canyon Member. The truncation of crosslaminae, together with cleavage, readily helps determine the tops of beds, even where the beds are isoclinally folded. This member weathers medium dark to light gray. An olive cast, combined with curved, shiny argillitic surfaces, helps distinguish this member from units other than the lower siltstone member. As in the lower siltstone member, graptolites are not very common. Those that have been found represent the Early Ordovician *Oncograptus* Zone. Three graptolite zones that occur in New Zealand between the *T. fruticosus* Zone and the *Oncograptus* Zone are missing from the Terra Cotta Mountains, suggesting a biostratigraphic break of unknown origin.

GRAPTOLITE CANYON MEMBER

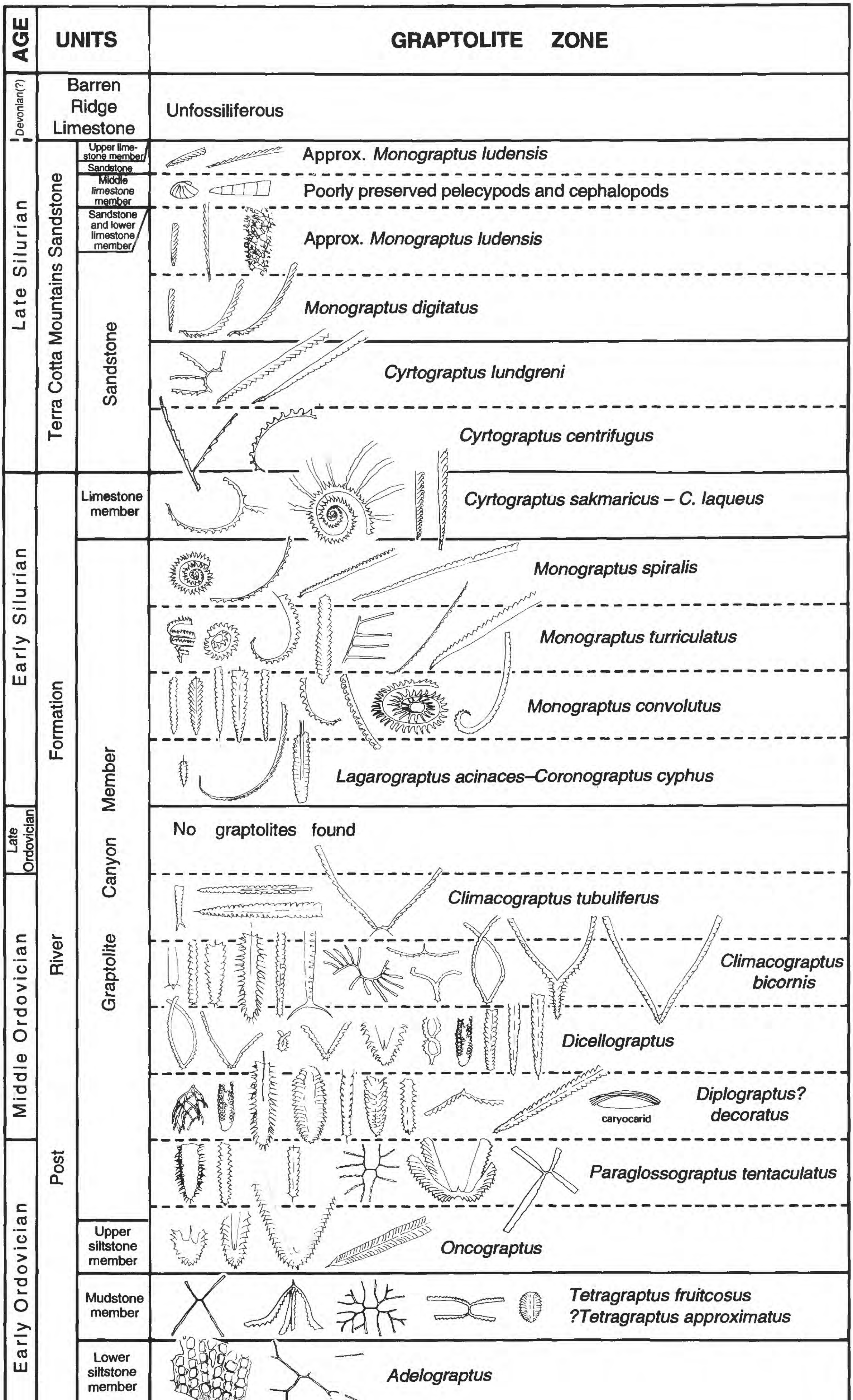
Most of the upper two-thirds of the Post River Formation consists of the Lower Ordovician to Lower Silurian Graptolite Canyon Member, which is chiefly dark-gray graptolitic shale that is named for Graptolite Canyon. Distinguishing features of the Graptolite Canyon Member are the preponderance of dark-colored shales and the abundance of graptolites on bedding planes. The only places within the member that graptolites were not found in abundance were along the crests of folds, where axial-plane cleavage splits the rock at sharp angles to the bedding.

At the type section (part of the Post River Formation type section, pl. 2, section 1), the Graptolite Canyon Member is about 220 m thick, but minor folding and faulting about 45 to 60 m above the base of the member are visible in the major outcrops. More than seven resistant, orange- and yellow-weathering argillaceous dolomite beds and lenses, ranging in thickness from 2.5 to 30 cm (pl. 3*B*; fig. 6), serve as marker units that locally indicate a few to several meters of offset on minor faults. The dolomitic beds and lenses are conspicuous only on cliff faces. Secondary dolomite cement, accompanied by veinlets of carbonate minerals, is also present.

The predominant lithology of the member is clay shale that readily splits along bedding and cleavage planes. In places, bedding is delineated by thin laminations of slightly coarser grained mudstone. However, the member is mostly a fissile shale that breaks into sheets as thin as a millimeter with smooth surfaces bearing silvery-looking flattened graptolites. The stratigraphically lower mudstone member, on the other hand, contains much more silt-sized detritus and breaks into thicker platy and slabby fragments with rough surfaces.

Figure 3. Type section of the Post River Formation, western flank of the Terra Cotta Mountains, Alaska. (See also pl. 3*B*, measured stratigraphic section.) View eastward up section includes the lower siltstone member (Opls) in foreground and bottom of gully, mudstone member (Opm), upper siltstone member (Opus), Graptolite Canyon Member (SOpg) in the intervening dark slopes, and limestone member (Spl). The Terra Cotta Mountains Sandstone (StII) is exposed on ridge top. About 300 m of section is exposed here. Minor faults, dikes, and folds affect lower part of section. Approximate line of measured section shown by heavy line on photograph and by dashed line on plate 2.

► **Figure 4.** Guide to graptolite faunas and other fossils in the Terra Cotta Mountains, Alaska.


AGE
UNITS
GRAPTOLITE ZONE
Devonian(?)
Barren Ridge Limestone
Unfossiliferous
Late Silurian
Terra Cotta Mountains Sandstone
Upper limestone member
Sandstone
Middle limestone member
Sandstone and lower limestone member
Sandstone
Approx. Monograptus ludensis
Poorly preserved pelecypods and cephalopods
Approx. Monograptus ludensis
Monograptus digitatus
Cyrtograptus lundgreni
Cyrtograptus centrifugus
Early Silurian
Post River Formation
Limestone member
Cyrtograptus sakmaricus – C. laqueus
Graptolite Canyon Member
Monograptus spiralis
Monograptus turriculatus
Monograptus convolutus
Lagarograptus acinaces–Coronograptus cyphus
Late Ordovician
No graptolites found
Middle Ordovician
Climacograptus tubuliferus
Climacograptus bicornis
Dicellograptus
Diplograptus? decoratus
caryocarid
Paraglossograptus tentaculatus
Early Ordovician
Upper siltstone member
Oncograptus
Mudstone member
Tetragraptus fruitcosus
?Tetragraptus approximatus
Lower siltstone member
Adelograptus

The second most important lithology in the Graptolite Canyon Member is a banded siliceous mudstone. This dark-gray, mainly argillaceous rock weathers blocky to slabby, instead of being fissile, and is more resistant to erosion (fig. 7). Original sedimentary layering, defined by slight changes in grain size and color, produce a laminated or banded appearance. These laminations are often cross cut and disturbed by very abundant cuneiform dark streaks. Their shape and internal structures closely resemble worm burrows found in modern-day deep-sea cores. These strongly bioturbated siliceous mudstones occur mainly in about the middle part to upper one-third of the formation (pl. 3*B*) where they form relatively resistant marker beds that can be traced in several places for more than 1.6 km (pl. 1). The banded mudstone is generally found at the same stratigraphic horizon as the *Climacograptus bicornis* Zone (Middle Ordovician) (pl. 3*B*; fig. 4). The intense bioturbation of the siliceous mudstones suggests that the graptolite-bearing, less siliceous shales may have lost a large percentage of their original graptolites if the burrowing was as extensive as in the mudstone. However, it is generally believed that the preservation of graptolites depended on anoxic conditions in the area of their deposition, a condition not generally compatible with a benthic, burrowing fauna. Therefore, where the shales are very rich in graptolites, they must not have been thoroughly bioturbated.

Figure 5. The lower siltstone member of the Post River Formation, Terra Cotta Mountains, Alaska. Closeup of thinly interbedded, very fine grained calcareous sandstone, siltstone, and silty limestone and minor, nearly pure fine-grained limestone. Argillaceous partings are olive gray and micaceous (phyllitic). Cross laminations and abundant load casts and current markings are well developed. Worm casts are common. Strata are in isoclinal folds that trend N. 5° E. and plunge 15° N. Axial planes of folds are subhorizontal and east-dipping at 25°, and many folds are overturned to the west. Rock is olive gray but weathers orange brown. SE¼ sec. 12, T. 24 N., R. 24 W., McGrath A-2 quadrangle, near peak 3710; collection site 69ACn482, near top of the lower siltstone member of the Post River Formation.

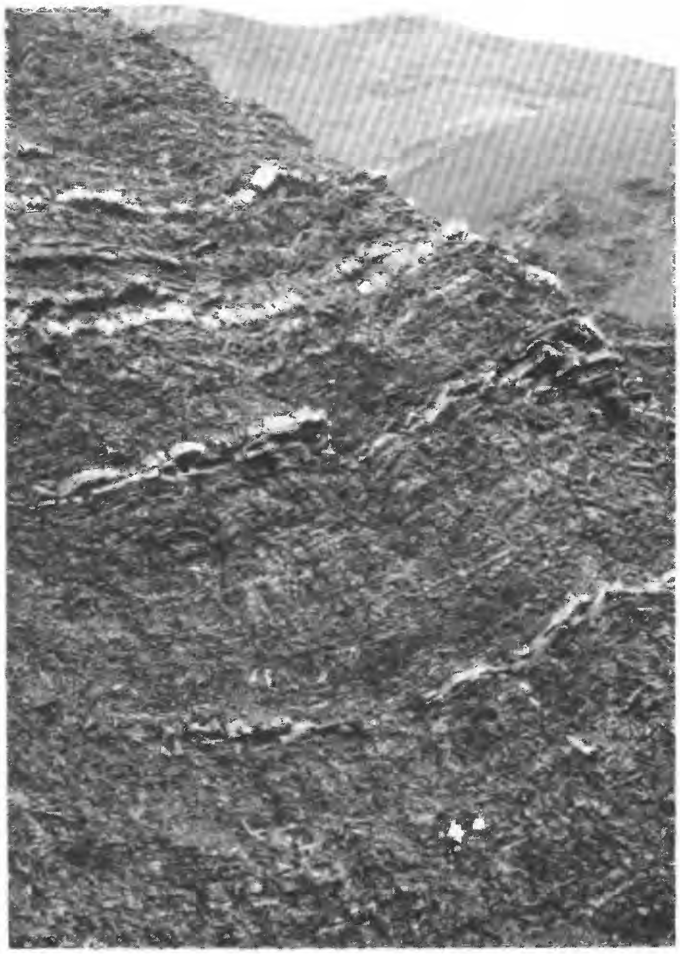


Figure 6. Lower part of the Graptolite Canyon Member of the Post River Formation, Terra Cotta Mountains, Alaska. Photograph of type section at collection site 69ACn545 (see pl.3*B*) shows thinly interbedded graptolitic shale, siliceous shale, and mudstone, with lighter colored yellowish- and orange-weathering argillaceous dolomite beds and lenses 10 to 30 cm thick. Graptolites in this interval belong to the upper part of the *Diplograptus*? *decoratus* Zone and to the *Dicellograptus* Zone of Middle Ordovician age.

In cliff outcrops, some of the banded mudstone is rhythmically bedded, with relatively resistant siliceous beds separated by softer shale partings (fig. 7). These beds physically resemble ribbon-bedded cherts. However, instead of fracturing conchoidally as chert does, the siliceous shales and mudstones fracture parallel to the laminations. Silt and very fine grained sand laminae often define bedding in these siliceous shales and mudstones.

The siliceous bioturbated mudstone that superficially resembles bedded chert has virtually no shale partings. Black lensing seams consist of fine clusters of iron oxides. Pyrite nodules are visible in outcrop, and finer opaque grains in thin section appear to be replacements of iron sulfides that were concentrated to some extent along bedding planes and in worm casts. In thin section (locality 69ACn571, pl. 3*B*), the silt-sized grains were found to be mostly angular quartz and well-twinned plagioclase (fig. 8).

The Graptolite Canyon Member conformably overlies the upper siltstone member. This contact is exposed just west and downslope of the crest of the Terra Cotta Mountains. Graptolites have been found about 7.5 m above the contact in the type section (colln. site 69ACn542, pl. 3*B*). The upper 45 m of the member is covered in the type section. However, in the reference sections (pl. 2, sections 4 and 5), graptolites were found in two localities 4.5 and 7.5 m below the overlying limestone member. In the canyon trending south-southwest from Camp #1 1969 (pl. 2, section 3), four structurally repeated limestones (pl. 2, colln. sites 69ACn411, 69ACn413,

Figure 7. Resistant, siliceous mudstone in upper part of the Graptolite Canyon Member of the Post River Formation, Terra Cotta Mountains, Alaska. Beds are 5 to 10 cm thick with very few softer shale partings. Rock is light to medium gray with prominent dark-gray worm casts that cut across bedding. Black, lensing laminae are also present. Pyrite nodules are common. Mudstone is about 15 m thick in upper one-third of the Graptolite Canyon Member in its type section. Probably locality 69ACn571 (pls. 2 and 3*B*).

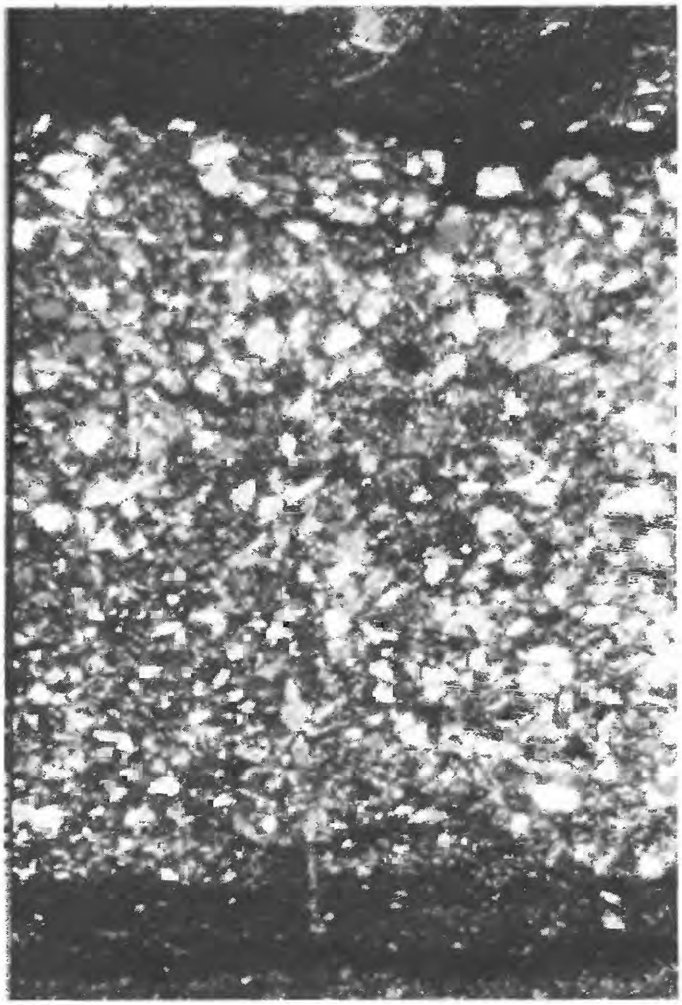


Figure 8. Thin section of banded mudstone from type section of the Graptolite Canyon Member of the Post River Formation, locality 69ACn571, Terra Cotta Mountains, Alaska. Angular silt grains are quartz and finely twinned plagioclase. Carbonate minerals, mainly dolomite, form cement and veinlets. Lens-like dark material is clusters of iron oxide minerals. Approximately ×45.

69ACn451, and 69ACn461) appear to belong to the limestone member. Silurian graptolites (collns. 69ACn461 and 69ACn413) are found in dark shales directly below this limestone. At locality 70ACn232 east of Camp #1 1970 (pl. 2), Silurian graptolites were found in siliceous shale at the top of the Graptolite Canyon Member directly below the limestone member. Several more collections of Silurian graptolites were made along the same contact (70ACn202, 70ACn532, 70ACn273, 70ACn281) in the uppermost part of the Graptolite Canyon Member. These graptolites are about the same age as those in the overlying limestone member, suggesting a conformable contact. Farther west, along the west limb of the Terra Cotta Anticline, a number of Early Silurian graptolite collections in sequence with Late(?) and Middle Ordovician graptolite horizons were collected in the upper part of the Graptolite Canyon Member (fig. 9; pl. 2, section 4). Although the *Monograptus spiralis* Zone fauna (fig. 4) was identified in dark siliceous shale 7.6 m below the limestone member, another structural repetition of this part of the section has apparently faulted out Silurian graptolite horizons below the limestone member, and graptolites of the much older *Climacograptus bicornis* Zone are juxtaposed against the limestone member (fig. 9; pl. 2, section 5).

The Graptolite Canyon Member is the most fossiliferous member of the Post River Formation. More than 70 graptolite collections were made in this member, and not every potentially graptoliferous horizon was sampled, due to talus cover. The graptolite faunas from this member represent six Ordovician biostratigraphic zones and four Silurian zones, ranging from Early Ordovician (Arenigian) through middle Early Silurian (fig. 4). There appears to be a gap in the highest Ordovician, and the Ashgillian graptolite zones, including the *Dicellograptus ornatus* Zone, have not been found in the Terra Cotta Mountains. The lowest Silurian graptolite zones of *Orthograptus acuminatus* and *Atavograptus atavus* are also unknown here. These highest Ordovician and lowest Silurian graptolite zones elsewhere are only several meters thick and, using radiometric age dating along with known accumulation rates, have been calculated to represent a relatively very brief period of geologic time (Churkin, Carter, and Johnson, 1977; Carter and others, 1980). Thus it is possible that a small amount of cover, such as occurs in this area, could prevent the recognition of several graptolite zones across the Ordovician-Silurian boundary.

The structural position of the two main outcrop belts of the Graptolite Canyon Member is along the flanks of the Terra Cotta Anticline. The right-side-up eastern flank of the anticline dips eastward an average of 35°. The western limb of the anticline clearly exhibits overturned beds of the upper part of the lower siltstone member, as revealed by the overturned crossbedding, graded beds, and load and current markings on the bottoms of siltstone beds. The western limb of this anticline is well exposed in the northwest quarter of sec. 19, T. 24 N., R. 23 W., along the cutbanks of the Post River (pl. 1), where the beds dip about 50° to the east and are overturned.

LIMESTONE MEMBER

The limestone member forms the upper part of the Post River Formation. The member is predominantly limestone but also contains minor amounts of shale. It forms a steep craggy slope just below the crest of the mountains and rims a narrow syncline about 300 m wide at an average elevation of 4,800 feet. The syncline axis caps the mountain top with olive-gray sandstone of the overlying Terra Cotta Mountains Sandstone.

In the measured section (pl. 3*B*), the lower 3 m of the limestone member consists of dark-gray shale interbedded with a subequal amount of limestone in beds 5 to 15 cm thick. The shale is soft and almost sooty in appearance. Farther down slope, the upper 45 m or so of the Graptolite Canyon Member is mostly covered. As the upper part of the Graptolite Canyon Member is poorly exposed, its exact relation with the overlying limestone member is not well understood, but the contact between the two members appears to be intercalated. Elsewhere the contact between the limestone member and the Graptolite Canyon Member is almost always covered. An exception is found along section *H-1* (pl. 1), where siliceous, dark gray shales with a *Monograptus spiralis* Zone fauna (figs. 4, 9; pl. 2, sections 4, 5) mark the top of the Graptolite Canyon Member. Overlying this is the dark-gray limestone of the limestone member, also containing coiled monograptids (figs. 4, 9).

The upper contact of the limestone member appears to be transitional because there is much calcareous cement in the first few feet of the overlying Terra Cotta Mountains Sandstone. The limestone member, although composed of a rock type that is not common in the Post River Formation, can be further distinguished by the fact that the limestone is thin-bedded and dark gray and is separated by graptolitic shale partings. The individual beds of limestone, averaging 2.5 to 5 cm thick, are internally laminated and have an overall dark-colored and more striped appearance than most of the limestones in the Terra Cotta Mountains Sandstone and the Barren Ridge Formation. This limestone member, unlike the younger limestone units, can be split into platy and slabby pieces along the shale partings and is the only limestone unit in which graptolites (monograptids) can be found with regularity. Monograptids are also abundant in the uppermost several meters of the underlying Graptolite Canyon Member. Figure 4 shows the characteristic graptolites of the limestone member as well as those of the other members of the Post River Formation.

The limestone member is about 18 m thick in the type section of the Post River Formation. In other places it is much thinner. For example, in the northern part of the map area (colln. site 70ACn755), the member is about 6 m thick. Here it is intruded by a dike and cut obliquely by a fault.

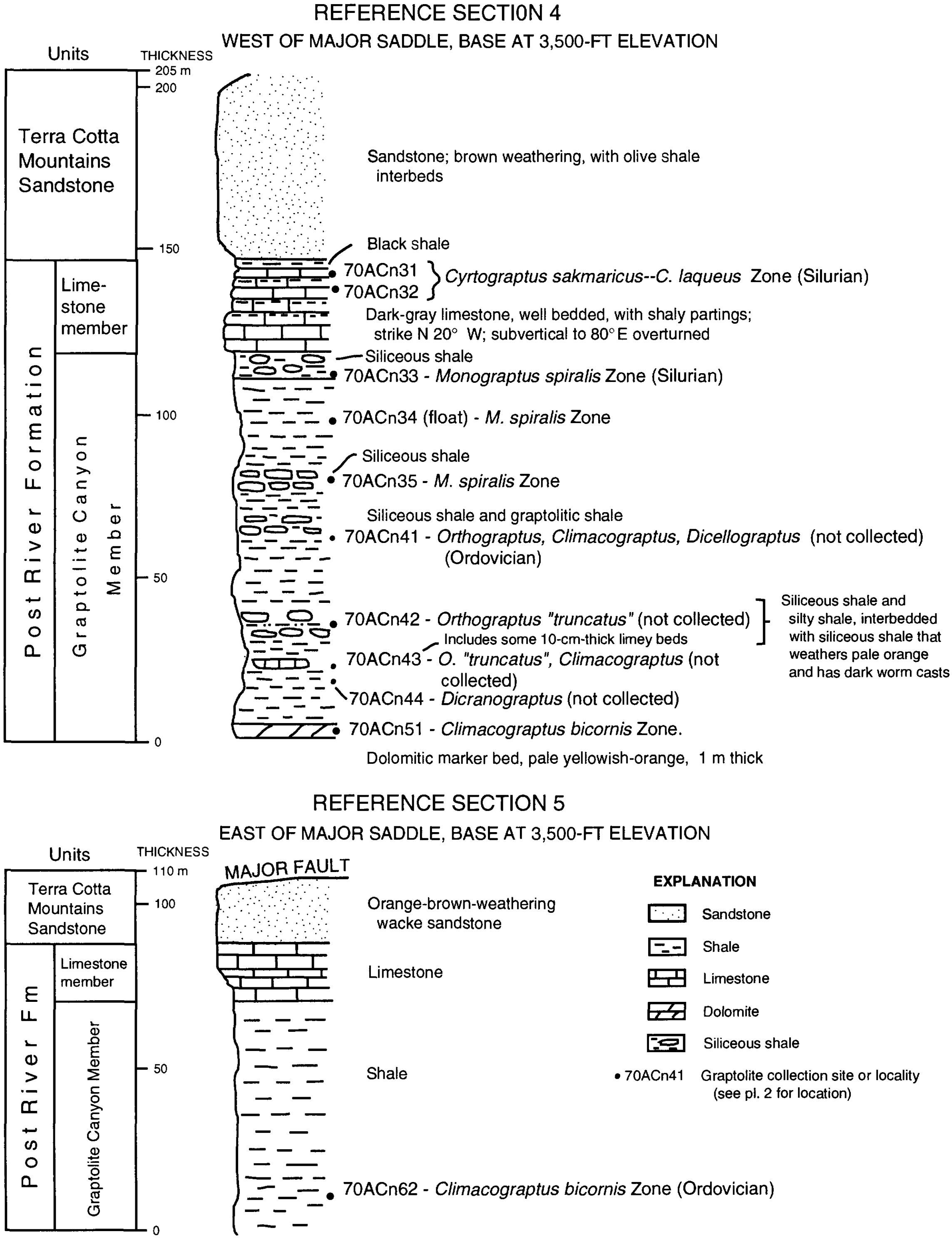


Figure 9. Columnar sections of the limestone member and upper part of the Graptolite Canyon Member of the Post River Formation, sec. 1, T. 24 N., R. 24 W., west side of Terra Cotta Mountains, Alaska, showing details of stratigraphy and graptolite faunal succession. See plate 2 for locations of reference sections and individual graptolite collections.

Thin sections of rock samples from the limestone member reveal calcite grains that appear rounded and detrital. Some rare detrital quartz grains also are present. Faulting occurs along the contact between the limestone member and the Graptolite Canyon Member in the southern and western parts of the map area. In some areas the Graptolite Canyon Member appears to be cut by thrust faults that attenuate the section and bring the upper siltstone member into close proximity with the limestone member (pl. 1). The limestone member is also exposed along a deep gully on the western flank of the mountains where it is closely associated in some tight folds with *Monograptus*-bearing shale of the upper part of the Graptolite Canyon Member (pl. 2, section 3).

TERRA COTTA MOUNTAINS SANDSTONE

The upper Lower and Upper Silurian Terra Cotta Mountains Sandstone is a newly named formation that is mainly composed of sandstone and mudstone but has three prominent limestone members. The formation is named for the Terra Cotta Mountains, to which it gives their terra cotta color and which are located in the southeastern part of the McGrath 1:250,000 quadrangle.

The Terra Cotta Mountains Sandstone is distinguished from other formations in the area by an abundance of rhythmically interbedded sandstone and mudstone. The rocks are generally coarser grained than clastic strata in the higher and lower parts of the section, and they have the prominent graded bedding and sole markings characteristic of turbidites.

The type section (pl. 2, section 6) of the Terra Cotta Mountains Sandstone is exposed along Graptolite Canyon. The section starts in the south fork of Graptolite Canyon and continues down the canyon to the junction with the main branch of the canyon. Reference sections for the Terra Cotta Mountains Sandstone are to the north (pl. 1, section *E-F)* and to the south (pl. 1, section *K-L-M*). In the vicinity of its type section, the Terra Cotta Mountains Sandstone consists of calcareous sandstone interbedded with mudstone for more than three-quarters of its total thickness. In addition, the formation contains three mappable limestone members that are described below.

The lower part of the Terra Cotta Mountains Sandstone consists of approximately 90 to 120 m of thick-bedded and massive sandstone with subordinate argillite or mudstone interbeds. These are the first coarse-clastic rocks encountered above the base of the section here. The sandstone and mudstone are a distinctive olive-brown color. In the basal part of the formation, the sandstone beds appear to be thicker and more massive and are a deeper shade of olive brown than beds higher in the section. The contact with the underlying dark laminated limestone that forms the top of the Post River Formation is sharp but accordant and appears to be conformable along section *J-K* (pl. 1), where the basal part of the Terra Cotta Mountains Sandstone forms a syncline. The lower part of the formation (sandstone with subordinate mudstone) is exposed for about 60 m along a tributary of Graptolite Canyon directly east of Camp #1 1970. The sandstone beds dip to the east and are right side up, as shown by their graded bedding. Argillite fragments and abundant mica characterize the coarser grained sandstones in this formation, particularly in the first and second cycles of sandstone above the base of the formation. In thin section, the sandstone is mainly composed of quartz and feldspar, and there is accessory muscovite and biotite. Many of the quartz grains are polycrystalline. The individual grains vary from angular to subrounded, but most are subangular. The sandstone is cemented by calcite, and many of the grains are replaced by carbonate minerals. The rock type, even in thin section, shows graded bedding. It is classified as a calcareous quartzo-feldspathic arenite, in which there is little matrix, and a quartzo-feldspathic wacke, in which the matrix is more than about 20 percent of the rock.

LOWER LIMESTONE MEMBER

Overlying the sandstone and mudstone at the base of the formation is a limestone member about 45 to 60 m thick. This stratigraphically lowest limestone in the map area is thick-bedded and relatively pure. It is medium dark gray and, in part, is mottled a very pale brown. Most of it is massive or blocky, but its basal part is laminated and platy. No megafossils have been found in it. In Graptolite Canyon, the lower limestone member is brecciated, veined with calcite, and irregularly replaced by orange-colored dolomite.

Overlying the lower limestone member is a well-bedded, medium-grained, medium-gray sandstone that weathers to tints of orange. This second, 150-m section of sandstone is interbedded with crosslaminated mudstone and argillitic shale. Individual sandstone beds average 0.6 to 0.9 m in thickness, and the more massive beds are characterized by load casts at their bases and readily visible graded bedding. Because less than 20 percent of the rock in the section here is argillaceous, the percentage of sandstone is higher than in the basal part of the formation.

A minor fault not shown on pl. 1 separates this sandstone and mudstone interval at type section 6 from an overlying thick-bedded limestone member that is replaced in places by orange dolomite. The structure here is not well known, and this middle limestone member may be a structural repetition of the lower limestone member of the Terra Cotta Mountains Sandstone.

MIDDLE LIMESTONE MEMBER

Farther east, along the main branch of Graptolite Canyon, the second sandstone interval is overlain by the middle limestone member, a dark-gray laminated limestone. This member (fig. 10) is generally thin bedded and platy. The laminations are accentuated by silt, mica, and argillaceous impurities. In contrast to other limestones in the area, the middle limestone member contains shelly fossils that were observed at several localities. These fossils include pelecypods and straight-shelled cephalopods that, unfortunately, are so poorly preserved that they have not been identified as to genus or age. A more intensive search, particularly at locality 70ACn551 (pl. 2), might yield better, age-datable material. The laminations in this member are generally planar, but at locality 70ACn551, near the top of the member, the lamination defines cross bedding. The limestone weathers various shades of gray, but in places it weathers orange. The thickness of this unit is difficult to estimate because of internal folding and the generally recessive nature of its outcrops. In most places it appears to be about 35 m thick, but it may be nearly 60 m thick in other places.

Another interval of sandstone, siltstone, and argillite, very much like that in the basal part of the formation, lies above the middle limestone member (fig. 10). This third cycle of siliciclastic strata is distinguished from the others by the presence near the base of a distinctive knobby limestone section 7.5 to 15 m thick. This knobby section consists of medium-dark-gray, finely crystalline limestone that weathers orange. The rock is characterized by thin, nodular or lensing bedding (fig. 11), and dolomite cement encloses the limestone lenses and nodules. The siliciclastic strata are further distinguished by the very fine grained sandstone, siltstone, mudstone, and shale that make up most of the interval and by the smaller amount of coarser sandstone than in the lower sandstone intervals of the Terra Cotta Mountains Sandstone. The stratigraphic details of this unit are obscured by a great deal of cover. Graptolites occur in several localities, but they are rare and difficult to find. They are all monograptids, apparently representing the *Monograptus ludensis* Zone (fig. 4). The total thickness of this third cycle of siliciclastic strata is about 90 m.

UPPER LIMESTONE MEMBER

Still farther east and downstream along Graptolite Canyon, the upper limestone member of the Terra Cotta Mountains Sandstone is exposed. This limestone is medium dark gray, is generally thick bedded and massive, and weathers medium gray. In places where it is thinner bedded and evenly laminated, it is slabby instead of blocky or massive. Domal-shaped structures that may represent stromatolites occur in this unit. Otherwise no fossils were noted.

This third and highest limestone member within the Terra Cotta Mountains Sandstone is much thicker than the other limestone members of the formation. In the southern part of the map area, it forms a wide outcrop belt culminating at Peak 5110. Estimates of its thickness along Graptolite Canyon range from about 90 to 120 m. Farther north, the upper limestone member thins to about 30 m. In Graptolite Canyon, the upper limestone member is folded into an asymmetrical anticline that is exposed 90 to 135 m along the canyon wall. The steep limb is to the west (upstream), and the eastern limb

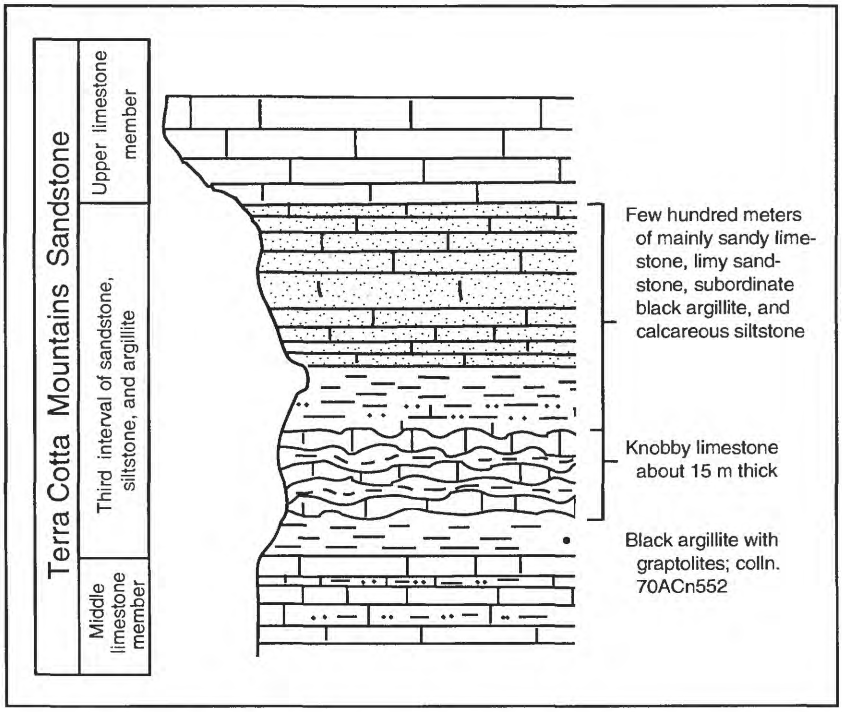


Figure 10. Generalized stratigraphic succession (not to scale) from the middle to the upper limestone members of the Terra Cotta Mountains Sandstone, Terra Cotta Mountains, Alaska.

dips more gently eastward. The limestone varies in bedding thickness from 1 cm to 1 m and has yellowish-orange argillaceous and shaly partings (fig. 12). The limestone itself is very dense, finely crystalline, and medium dark gray, weathering to medium gray.

The stratigraphically highest part of the Terra Cotta Mountains Sandstone is a calcareous siltstone and sandstone interval not unlike the three underlying siliciclastic cycles. This interval appears to be a still finer grained equivalent of the basal, more sandstone-rich lowest cycle. Shales with phyllitic partings are common, as are argillaceous and silty limestone beds that weather slabby. This interval is about 90 to

Figure 11. Steeply dipping, very thinly interbedded limestone and calcareous siltstone and mudstone of Terra Cotta Mountains Sandstone, Terra Cotta Mountains, Alaska. Lighter colored limestone layers are dark gray on fresh surfaces and are very fine grained, dense limestone with small pyrite cubes. Argillaceous layers are olive gray to light brown. Lensing layers of purer limestone produce a knobby appearance that characterizes the unit. Abundant small pyrite cubes in dense limestone suggest that a reducing environment affected the sediments. Location is Graptolite Canyon at elevation 3,700 feet, where a minor north tributary meets Graptolite Canyon (pl. 2, loc. 70ACn243).

Figure 12. Upper limestone member of the Terra Cotta Mountains Sandstone, Terra Cotta Mountains, Alaska. Resistant beds, 1 cm to 1 m thick, of massive to blocky, dense, finely crystalline limestone interbedded with slabby limestone beds, 0.3 to more than 1 m thick, that have argillaceous and silty partings. Purer limestone beds are medium dark gray, weathering to medium gray. Argillaceous limestone is medium gray under overhangs but generally weathers yellowish orange. Purer limestone beds have clastic texture produced by irregular and angular limestone fragments in limestone cement. Minor amounts of silt-sized quartz and plagioclase are also present. Thin sections show that limestone cement is interlocking mosaic of calcite crystals and carbonate clasts are fragments of very fine grained calcite. Abundant small cubes of pyrite in dense limestone suggest that a reducing environment affected the sediments. Exposure is along Graptolite Canyon creek downstream from its northern tributary, center sec. 5, T. 24 N., R. 23 W., (pl. 2, loc. 70ACn342). Beds dip gently eastward (to the right and downstream) on east limb of an asymmetrical anticline that has steeply west dipping beds (strike N. 10° E., dip 75° W.) about 150 m to the west. Backpacks in foreground show scale.

150 m thick. Load casts and crosslaminations characterize the siltstone and sandstone, and many of the weathered scree slabs are ropy and elliptical in shape because of the pinch-and-swell original bedding (fig. 13). A single bed of limestone edgewise conglomerate occurs in this interval in the southern part of the area (see description of structure section *J-K-L-M*). The conglomerate is interpreted as a channel deposit within this sequence of turbidites.

In a small northeasterly trending canyon tributary to Graptolite Canyon (W1/2 sec. 4, T. 24 N., R. 23 W.), the highest beds in the Terra Cotta Mountains Sandstone and the lowest beds of the Barren Ridge Limestone are exposed (pl. 1). At elevation 3,550 ft along this tributary, the Terra Cotta Mountains Sandstone occurs as beds of calcareous siltstone and sandstone with occasional thin interbeds of pure, medium-gray limestone with abundant pyrite cubes. These beds strike N. 75° W. and dip 30° NE. Cleavage is well developed, and numerous mafic sills cut the section. At elevation 3,650 ft, beds considered to be the basal part of the Barren Ridge Limestone and consisting of nearly pure limestone strike N. 30° W. and dip 30° NE. Because of the change in strike of the beds across the contact between the two formations, plus the abrupt thinning of the uppermost siliciclastic member of the Terra Cotta Mountains Sandstone north of Graptolite Canyon (pl. 1), an important bedding-plane thrust fault is thought to exist along the contact.

Figure 13. Calcareous siltstone and sandstone interval of the Terra Cotta Mountains Sandstone, Terra Cotta Mountains, Alaska. Cross-laminated calcareous sandstone and siltstone with disseminated pyrite cubes; load casts occur on bottoms of beds. Beds strike north-south, dip 60° E., and are overturned. Probably stratigraphically highest rocks of the Terra Cotta Mountains Sandstone, located in sec. 5, T. 24 N., R. 23 W., along north bank of Graptolite Canyon creek, downstream and stratigraphically above locality 70ACn342 (pl. 2).

BARREN RIDGE LIMESTONE

The Barren Ridge Limestone is a newly named formation of Devonian(?) age that is predominantly limestone. The formation is named for an arcuate mountain ridge, Barren Ridge, that reaches an elevation of 5,400 ft along the eastern part of the map area in the southeastern part of the McGrath 1:250,000 quadrangle. Although a prominent unit in the area, it is the least well known because it is unfossiliferous and because the lack of obvious marker beds make it difficult to observe the stratigraphic succession within the formation.

The type section of the Barren Ridge Limestone is located along the crest of the narrow Barren Ridge that lies on the north side of the lower reaches of Graptolite Canyon (pl. 2, type section 7). The base of the section starts at 4,300 feet above sea level, just below elevation point 4,530, and runs northeastward along the crest of the ridge into the western part of sec. 35, T. 25 N., R. 23 W., McGrath quadrangle, where the dip of predominantly eastward-dipping strata reverses direction. A synclinal axis is exposed here, and the dips change to westerly and northerly. Along the middle part of the ridge crest (sec. 4, T. 24 N., R. 23 W., McGrath quadrangle), an overturned syncline parallels the ridge crest. Another overturned syncline, with both limbs dipping eastward, occurs farther to the northeast in another structurally controlled ridge crest that trends northeasterly along the east edge of sec. 35, T. 25 N., R. 23 W. (pl. 1). Fold axes are gently dipping or nearly horizontal.

Internal folding in the Barren Ridge Limestone can be seen near Camp #2 1970. Here another syncline trends northerly and is overturned to the west. The dips are predominantly eastward and range from 35° E. to subvertical. Further evidence of internal folding and faulting in the Barren Ridge Limestone is provided by some relatively massive limestone marker beds within the formation that are exposed along the south side of Barren Ridge. Faulting and folding also seem responsible for the irregular outcrop pattern of a calcareous siltstone member within the formation. Because of the structural uncertainties and only partial mapping of the Barren Ridge Limestone, particularly to the east, its upper contact is unknown. Its lower contact with the Terra Cotta Mountains Sandstone in Graptolite Canyon may be a thrust fault subparallel to bedding. Unfortunately, the contact between these two formations directly north of Graptolite Canyon is mainly covered by scree.

The stratigraphic succession in the Barren Ridge Limestone is known mainly from observations made in Graptolite Canyon and on ridges and slopes extending north of the canyon to the crest of Barren Ridge. A traverse along section *E-F-G* (pl. 1) runs easterly and southeasterly through the Terra Cotta Mountains Sandstone and the Barren Ridge Limestone to the top of the ridge. Along this section, the Barren Ridge Limestone appears to be composed of two more-or-less pure limestone members separated by a siltstone member of calcareous siltstone and sandy limestone (fig. 14). These members are described individually below.

LOWER LIMESTONE MEMBER

The lower limestone member is found along the north side of Graptolite Canyon. At elevation 4,350 ft, the basal part of the Barren Ridge Limestone is defined by a limestone section that extends up to an elevation of 4,700 ft. About 70

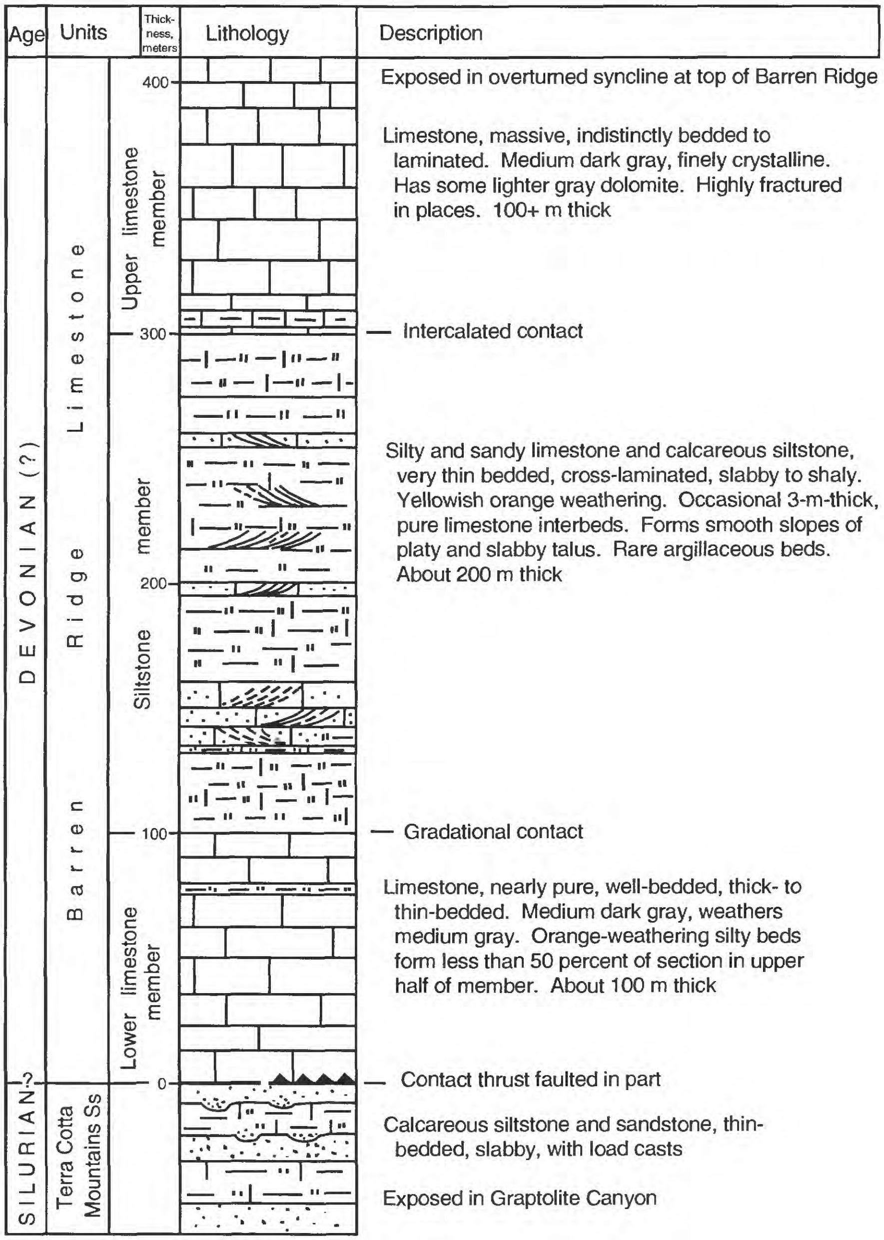


Figure 14. Generalized stratigraphic succession within the three members of the Barren Ridge Limestone, Terra Cotta Mountains, Alaska. Thicknesses are approximate.

to 80 percent of the section is medium-dark-gray limestone that weathers medium gray. Finely crystalline limestone forms beds that are interlayered with silty limestone to produce the appearance of cyclical bedding. In the upper half of the member, subordinate orange-weathering silty beds form much less than 5 percent of the section.

SILTSTONE MEMBER

The siltstone member of the Barren Ridge Limestone is a unit of mainly very thin bedded (1.3–5 cm thick) calcareous siltstone and sandy limestone. The sandy limestone is medium grained and crosslaminated. None of the limestone in this member appears to be as pure as that in the lower member. The siltstone member forms smooth slopes of platy and slabby scree unlike the more blocky, rough talus of the underlying lower limestone member. At elevation 4,350 ft in the tributary canyon, the siltstone member of the Barren Ridge Limestone strikes N. 65° E. and dips 20° N. At 4,600 ft elevation, the sandy and silty limestone and calcareous siltstone and sandstone is overlain by a platy, calcareous siltstone and some sandstone that form an even smoother slope than that below. This section of relatively less resistant siltstone and sandstone is about 150 m thick.

UPPER LIMESTONE MEMBER

The siltstone member is overlain by massive, medium-dark-gray, finely crystalline limestone. The bedding in most places is fairly distinct, and laminations frequently can be seen. This relatively pure limestone is highly fractured at elevation 4,950 ft in the tributary canyon, and some irregular layers of lighter gray dolomite appear to be a secondary replacement. At the intercalated contact between the upper limestone member and the siltstone member, 3-m-thick limestone beds are separated by 6-m-thick silty and sandy beds (fig. 15).

On top of Barren Ridge itself, at elevation 5,400 ft, the upper limestone member is well bedded to laminated and has minor yellowish-orange, silty limestone interbeds (fig. 16). Pinkish-orange-colored dolomite forms irregular layers, and the limestone is cut by white dolomite veinlets. On peak 5450, the limestone of the upper limestone member is silty and sandy and again is well bedded and crosslaminated. Pure limestone

Figure 15. Upper limestone member of the Barren Ridge Limestone, Terra Cotta Mountains, Alaska. Light-colored craggy exposures at top of ridge are nearly pure limestone. Dark irregular rocks in middle bluff are intrusive sills and dikes of mafic composition. Smooth, mainly talus slopes in lower part of photograph are orange-weathering platy calcareous siltstone and some sandy limestone of the siltstone member of the Barren Ridge Limestone. Contact between middle and upper members of the Barren Ridge Limestone is at about elevation 4,400 to 4,700 ft along west side of ridge crest at southern end of Barren Ridge (sec. 4, T. 24 N., R. 23 W., McGrath A-1 quadrangle).

forms about 50 percent of the section here. Some rare shale also occurs in the section.

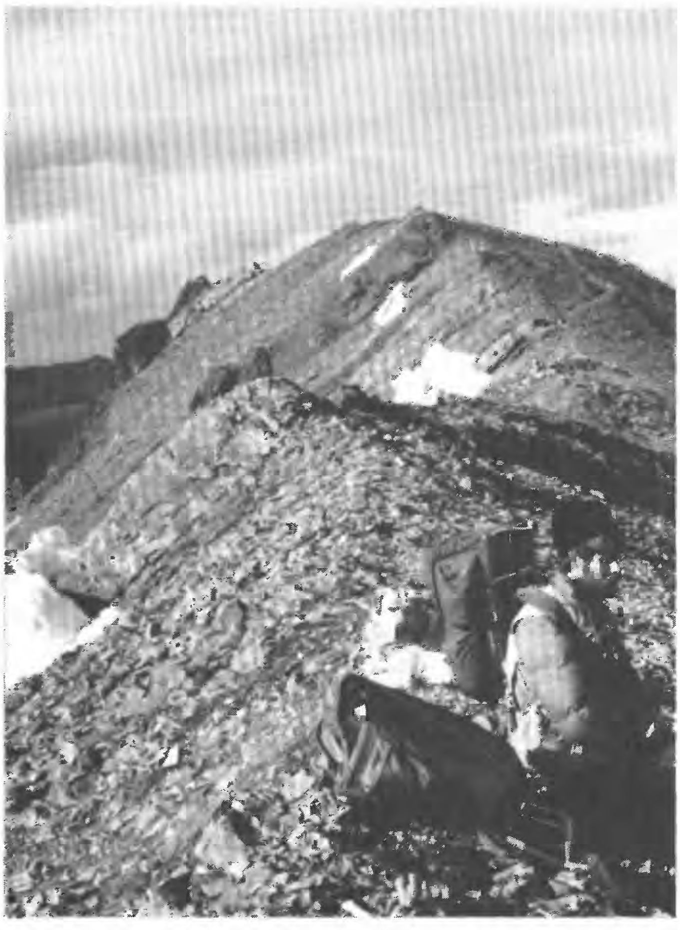
STRUCTURE OF THE TERRA COTTA MOUNTAINS

REGIONAL STRUCTURAL SETTING

The structure and stratigraphy of the Terra Cotta Mountains was briefly described by Spurr (1900; p. 119–121; p. 156–157). His original description indicates that the Terra Cotta Mountains parallel an anticlinal structure. An anticlinal structure is confirmed in the southern end of the Terra Cotta Mountains by Bundtzen and others (1987) and by our mapping (pl. 1). On the other hand, the rapid reconnaissance traverse by Spurr indicated that "the rocks of the Terra Cotta Series are considerably and often confusedly folded, the folds being broken and complicated by the intrusive rocks." Spurr reported dikes and sheets of igneous rocks and thought that the sedimentary series itself probably contained interbedded volcanic rocks. Recent work, however, shows that, except for some minor sheared greenstone in the lower siltstone member of the Post River Formation, there are no volcanic rocks in the Paleozoic sedimentary sequence here and that only a few locally important igneous intrusions occur within the map area (Bundtzen and others, 1987). The structural details identified in our mapping indicate a penetrative style of folding, as seen by a rather regular orientation of folds, cleavage, and associated thrust faults.

Except for the original exploratory traverses by Spurr, no mapping or structural study of this area took place until the late 1960's when the U.S. Geological Survey started mineral-resource investigations in this part of the southern Alaska Range (Reed and Elliot, 1968a, b). Systematic geologic mapping of the area, begun in 1977 by the Alaska Division of Geological and Geophysical Surveys, resulted in a series of large scale (1:63,360 and 1:40,000, high-quality geologic maps (Bundtzen and others, 1982, 1987; Gilbert and others 1982; Gilbert and Solie, 1983; Kline and others, 1986). These maps show much structural detail and accurately depict the various rock sequences in the region. They also demonstrate that the Farewell Fault, as part of the Denali Fault System, separates the sequence of lower Paleozoic units described in this report from a mainly younger, less highly deformed, lithologically very different sequence of rock units north of the fault system (Bundtzen and others, 1982; Gilbert and others, 1982; Kline and others, 1986).

The different geologic histories reflected in the geologic sequence on both sides of the Farewell Fault have been outlined by Gilbert and Bundtzen (1983). The lack of any direct stratigraphic correlation between rock sequences on the north and south sides of the Farewell Fault, together with the very different geologic histories of rocks across the fault, has necessitated the division of these geologic sequences into different tectonostratigraphic terranes (Jones and others, 1982; Bundtzen and others, 1982; Bundtzen and Gilbert, 1983; Gilbert and Bundtzen, 1984; Kline and others, 1986). Paleozoic rocks south of the Denali-Farewell Fault are assigned to the Dillinger terrane (Jones and others, 1982) or to the (composite) Dillinger-Mystic terrane (Gilbert and Bundtzen, 1984; Bundtzen and others, 1987), whereas the Devonian carbonate rocks north of the fault are assigned to the Nixon Fork terrane (Bundtzen and Gilbert, 1983, p. 104). According to Bundtzen and Gilbert (1983), the Dillinger rocks are considered to be an offshore distal-turbidite-rich facies of the Nixon Fork carbonate platform rocks. A similar interpretation that



◀ **Figure 16.** The upper limestone member of Barren Ridge Limestone, Terra Cotta Mountains, Alaska. Mainly limestone with minor interbeds of thin shale. Limestone is well bedded, laminated in places, and slabby. Pure limestone is medium dark gray and weathers medium gray. Some rare, irregular, pinkish-orange or white dolomite veinlets are present. Brownish-gray shale in 15-cm beds forms about 70 percent of section. Minor crosslaminae of fine-grained sandy limestone are present here. View north along tip of Barren Ridge at elevation 5,400 ft, where ridge crest parallels strike of beds (N. 45° E.) and beds dip 65° N.W., forming craggy, northwesterly dip slopes (left side of photograph).

the Terra Cotta Mountains sequence is a somewhat structurally displaced but not totally exotic sequence when compared to the Nixon Fork carbonate platform rocks was proposed earlier by Churkin, Carter, and Trexler (1980). They described it as a shale-out facies of the carbonate platform of continental-margin proportions. The tight isoclinal folding and imbricate thrust faulting within the sequence exposed in the Terra Cotta Mountains suggested to these workers that the stratigraphic relations had been telescoped. The width of the Paleozoic outcrop gives a false impression of the thickness of the formations. For example, in the McGrath B-2 quadrangle (Bundtzen and others, 1982) and the adjoining B-3 quadrangle (Gilbert and others, 1982), the lower Paleozoic sequence of the Terra Cotta Mountains extends about 32 km west across strike before it is terminated by the Farewell Fault next to the Windy Fork of the Kuskokwim River. The Terra Cotta Mountains Sandstone is exposed across most of this distance, and the Post River Formation is exposed only in two overturned anticlines. These anticlines occur along the west front of the Terra Cotta Mountains and along Sheep Creek (fig. 1), where mapping and graptolites collected by Rod May in 1969 demonstrate the presence of the Graptolite Canyon Member of the Post River Formation. The presence of this type of isoclinal folding within the tripartite stratigraphic sequence in the Terra Cotta Mountains, the fact that numerous bedding plane shears and thrusts can be observed, and the fact that no rigid basement has been encountered below the Post River Formation all indicate that the Paleozoic sequence in the Terra Cotta Mountains is decoupled from its basement and represents a highly deformed allochthon. When the stratigraphic thickness (less than 1,500 m) of the allochthon is compared with the width of its outcrop (more than 40 km) from the Windy Fork across the Terra Cotta Mountains to the South Fork of the Kuskokwim River, it becomes clear that the allochthon represents a relatively thin sheet that is highly deformed internally. Bundtzen and others (1987) estimate 20 to 25 km of crustal shortening within the McGrath A-2 quadrangle.

The amount of strike-slip displacement along the Farewell Fault System is not known. Offset plutons along the Denali Fault System, of which the Farewell Fault is a part, indicate a right-lateral displacement of about 38 km during the past 38 m.y. (Reed and Lanphere, 1974). Bundtzen and Gilbert (1983) estimate about 60 km of displacement during the past 60 m.y., but the amount of total displacement could be much larger because lithic similarities between the sequence in the Terra Cotta Mountains and rocks in the Selwyn Basin of the Yukon Territory suggest an originally closer connection (Churkin and others, 1984).

STRUCTURE AND TECTONICS OF MAPPED AREA

The overall structure of the map area is that of a large asymmetrical anticline, the axis of which trends northerly along the west margin of the Terra Cotta Mountains. In the northern part of the area and continuing north toward the Farewell Fault, the axis of the anticline, named the Terra Cotta Anticline (Bundtzen and others, 1982; 1987), curves gently to the northeast, attaining a strike of N. 20° E. In the McGrath C-1 quadrangle to the northeast, the Paleozoic sequence swings even farther east along the south side of the Farewell Fault, where the strike is about N. 60° E. The Terra Cotta Anticline is overturned to the west (figs. 17, 18). Beds along its axis generally dip 35° to 50° E., but locally dip as little as 20° E. The lower siltstone member of the Post River Formation is exposed in the core of the anticline, and numerous minor folds, on the scale of a few centimeters to a few meters, occur as asymmetrical drag folds on the limbs of the major fold (fig. 19). A strong, east-dipping cleavage parallels the fold axis and appears to be axial-plane cleavage that symmetrically bisects the microfolds (fig. 20). Graded bedding, bottom-current markings, and other features characteristic of turbidites in the lower siltstone member also indicate that the west limb of the anticline is locally overturned. Beds on the east limb dip predominantly eastward from about 70° to 30°, although many dip reversals and internal folds are on the scale of a few centimeters to a few meters (fig. 20). Synclines formed in the basal part of the Terra Cotta Mountains Sandstone have been mapped for as much as 0.8 km along strike (pl. 1). Another major fold axis appears to form Barren Ridge, where a westward-overturned syncline is seen in the upper part of the Barren Ridge Limestone. Minor folds within each stratigraphic unit make it difficult to measure true original thicknesses of beds.

Thinning of the section within the Post River Formation, particularly within the Graptolite Canyon Member near Camp #1 1969, suggests the presence of thrust faults that are subparallel to bedding. Generally, where bedding-plane shear and thrusting are present, the faulting has brought older beds over younger. A major thrust south of Camp #1 1969 brings the lower siltstone member structurally over the Graptolite Canyon Member (pl. 1). In one place along the trace of this thrust, all of the Graptolite Canyon Member is cut out by the fault and the lower siltstone member rests structurally on the Terra Cotta Mountains Sandstone. Intraformational faulting is also thought to occur near Camp #1 1970 and extends on strike 3.2 km to the south. Here the lower contact of the Terra Cotta Mountains Sandstone appears to truncate various horizons of the Graptolite Canyon Member and the upper siltstone member of the Post River Formation (pl. 1). The fault appears to bring younger rocks over older rocks. The thick and mechanically more resistant sandstones and limestones of the Terra Cotta Mountains Sandstone apparently ramped over the much less competent shales of the Graptolite Canyon Member. A similar younger-on-older fault may mark the contact of the uppermost part of the Terra Cotta Mountains Sandstone and the overlying lower limestone member of the Barren Ridge Limestone. North of our map area, in the McGrath B-2 quadrangle, Bundtzen and others (1982) have mapped another younger-on-older fault along Sheep Creek, where Ordovician graptolite shale (their map unit Osh) in the lower plate is overthrust by Silurian sandstone (their map unit Sas) in the upper plate.

STRUCTURE SECTIONS

The following detailed descriptions of two cross sections across the Terra Cotta Mountains (pl. 1) reiterate the lithology and structure discussed previously and are intended to fully document the geology and to enable future workers in the area to accurately locate pertinent features.

SECTION *H-I*

This section includes the Post River Formation and the lower part of the Terra Cotta Mountains Sandstone. Although the section crosses steep cliffs in its western and eastern parts, it is a good, representative structural traverse across the Terra Cotta Anticline and contains at least 13 separate graptolite horizons that provide precise age and stratigraphic control. The section reveals a large recumbent anticline, whose eastern, right-side-up limb forms the western crest of the Terra Cotta Mountains. Between graptolite localities k and l (pl. 1), at elevation 4,700 feet, fine-grained calcareous sandstone and phyllitic shale are thinly interbedded, and the slope is covered with platy orange-weathering sandstone, siltstone, and shale debris. These beds belong to the upper siltstone member of the Post River Formation. They strike N. 20° W. and dip 35° E., and crosslamination indicates that their tops are to the east. About 15 m stratigraphically higher, to the east and downslope from here, graptolites and caryocarids of the *Diplograptus*? *decoratus* Zone were collected (pl. 2, colln. site 70ACn301) from dark-gray fissile shale of the Graptolite Canyon Member of the Post River Formation. To the west, near the crest of the mountain at 5,090 ft, is graptolite collection site 70ACn312 (pl. 1, loc. k; pl. 2) that contains a sparse fauna of the *Tetragraptus fruticosus* Zone (fig. 4). It was collected from the mudstone member of the Post River Formation, which consists of dark-gray mudstone characterized by uneven and sandy-appearing bedding planes stained rust-colored by iron oxides. The beds at this locality strike N. 20° W. and dip 35° E.

Stratigraphically below the mudstone is the thick, internally folded and faulted, calcareous siltstone and sandstone unit with phyllitic shale interbeds that is designated as the lower siltstone member of the Post River Formation. It is characterized by crosslamination and a medium-light-gray to olive-gray color that weathers olive or yellowish brown. About 0.5 km to the west, at an elevation of 4,000 feet, lithically similar beds of calcareous siltstone and fine-grained quartzose sandstone with

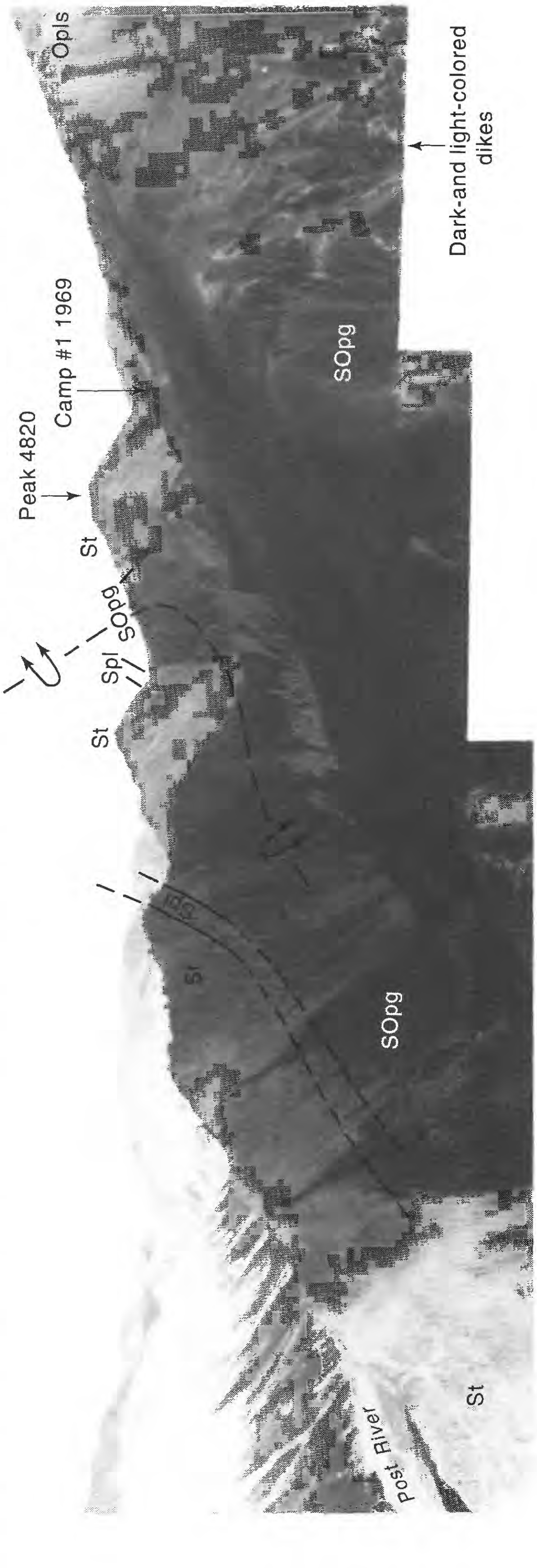


Figure 17. Panoramic view north along axis of Terra Cotta Anticline, which parallels steep western flank of Terra Cotta Mountains, Alaska. Photographs taken from near Camp #2 1969 (pl. 2). On left (west) side of photograph, west-dipping resistant sandstone (St) of basal part of the Terra Cotta Mountains Sandstone overlies cliff exposures of dark and light, well-bedded limestone and shale (Spl) of uppermost part of Post River Formation. Dark, nearly black slopes of Graptolite Canyon Member (SOpg) of Post River Formation underlie unit Spl and form dark saddles in ridge crests along axis of north-trending, steep anticline. Rocks in right foreground are overturned beds of the lower part of the Post River Formation (Opls). Resistant light- and dark-colored rocks that form sinuous outcrops are felsic and mafic dikes, respectively.

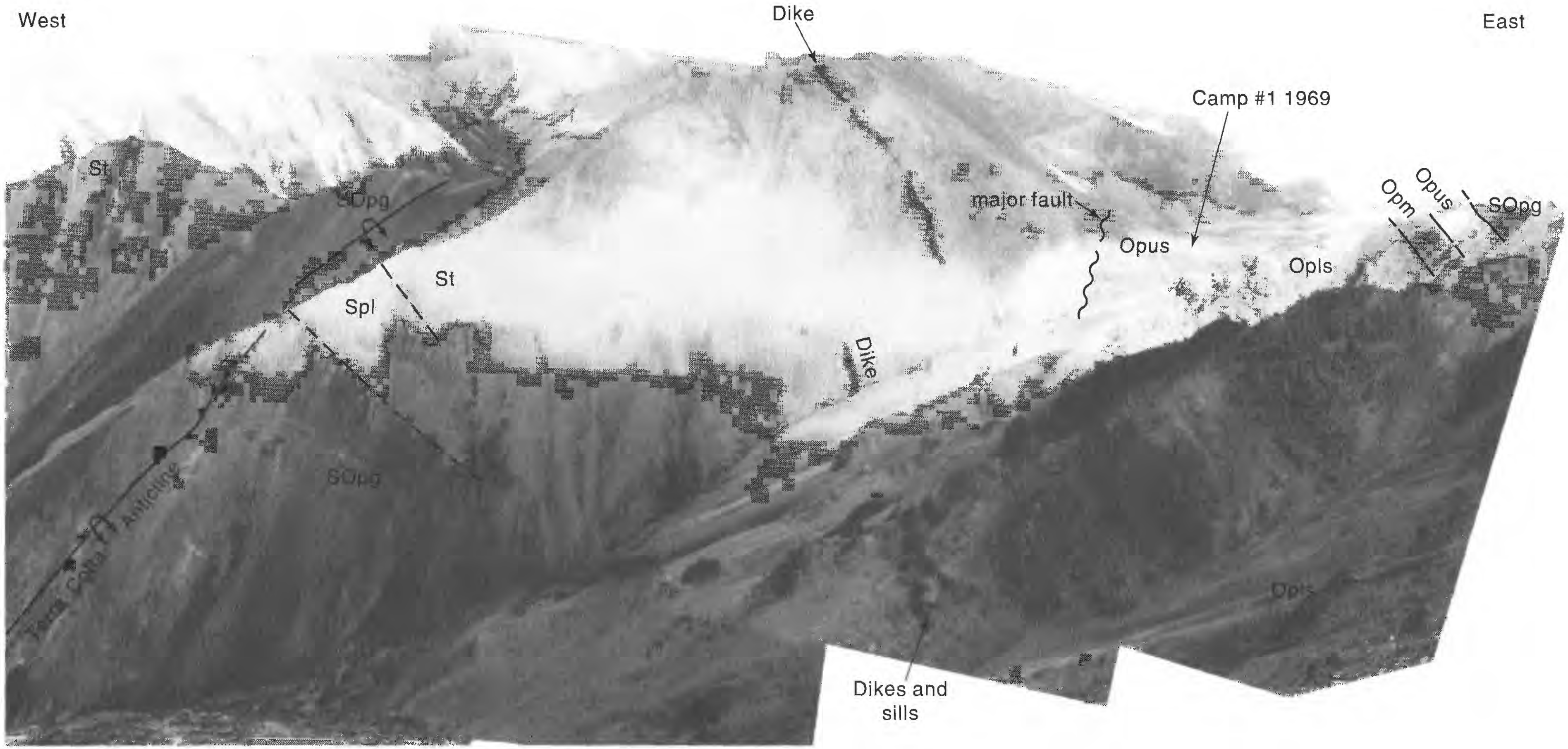


Figure 18. Core of Terra Cotta Anticline, view northwest from near Peak 3830 into south-trending deep canyon in SE1/4 sec. 32, T. 25 N., R. 23 W. Canyon cuts west flank of Terra Cotta Mountains, Alaska. Dark graptolitic shales of Graptolite Canyon Member (SOpg) of Post River Formation form lower slopes to left. Stratigraphically higher are light-gray beds of limestone member (Spl) of Post River Formation, and brown, blocky outcrops of sandstone of Terra Cotta Mountains Sandstone (St). Major, high-angle thrust fault brings lower siltstone member (Opls), as well as mudstone member (Opm), upper siltstone member (Opus), and Graptolite Canyon Member (SOpg), of Post River Formation over the Terra Cotta Mountains Sandstone. Dark mafic dikes cut the lower siltstone member in foreground, extend on strike across fault, and cut Graptolite Canyon Member and Terra Cotta Mountains Sandstone. Skyline roughly parallels cross section *A-B-C* on plate 1.

subordinate argillite strike N. 40° W. and dip 25° E. According to crosslaminations and current structures on the bases of individual beds, these beds are overturned to the west. The craggy, light-colored outcrops between here and the top of the mountain are formed in the lower siltstone member (fig. 21). Here, the top of the lower siltstone member is overlain down slope by black shale that may belong to the mudstone member. About 25 m stratigraphically higher but downslope in overturned beds, graptolite collection 70ACn82 (pl. 1, loc. j; pl. 2), representing the *Oncograptus* Zone, was found in shale interbedded with calcareous siltstone. These beds apparently represent the upper siltstone member of the Post River Formation. Down-slope from the conspicuous saddle at elevation 3,500 feet is a succession of dark-gray graptolitic shales with faunas that represent the *Paraglossograptus tentaculatus, Diplograptus*? *decoratus,* and *Climacograptus bicornis* Zones. Rare, orange-weathering lenses of dolomite are interlayered with the dark-gray, graptolitic shale of the higher graptolite zone (pl. 1, loc. f; pl. 2, colln. site 70ACn62). These beds belong to the Graptolite Canyon Member of the Post River Formation. In the saddle at 3,500 feet, dark-colored thin-bedded limestone is associated with a small patch of orange-brown-weathering wacke sandstone. These lithologies resemble those of the limestone member of the Post River Formation and the Terra Cotta Mountains Sandstone. This long triangular belt composed of the uppermost part of the Post River Formation and lowermost part of the Terra Cotta Mountains Sandstone thickens rapidly northward and appears to be an overturned syncline faulted out on its southwestern side (pl. 1; fig. 9). Several kilometers farther north on strike (pl. 1, section *A-B*), the Terra Cotta Mountains Sandstone is folded into a recumbent syncline that is overridden by the lower part of the Post River Formation on its eastern side.

On the west side of the saddle at elevation 3,500 feet (east-central part of sec. 1, T. 24 N., R. 24 W.) in rocks of the Graptolite Canyon Member, is another sequence of overturned-to-the-west graptolite zones (fig. 9, colln. sites 70ACn31 to 70ACn51) that decrease in age to the west, from the Middle Ordovician *Climacograptus bicornis* Zone to the Early Silurian *Monograptus spiralis* Zone. This sequence is overlain by the limestone member of the Post River Formation, which is about 23 m thick here and contains graptolites of the *Cyrtograptus sakmaricus–C. laqueus* Zone (colln. site

Figure 19. Folded lower siltstone member of the Post River Formation, consisting of thinly interbedded, silty and phyllitic shale and calcareous, fine-grained sandstone. Calcareous sandstone beds are more resistant and weather light orange. Darker argillite beds are olive gray to dark gray. Limey beds pinch and swell, and their original lens shape is accentuated by tectonic thinning and thickening. Western (left) limbs of these asymmetric folds are steeper and shorter than eastern limbs. Drag folds are on eastern, upright limb of the much larger, recumbent Terra Cotta Anticline, the axis of which lies farther west. View north from north bank of the Post River, south-central Alaska, just west and stratigraphically below locality 70ACn122 (pl. 2).

70ACn31). The limestone dips subvertically to 80° E. (overturned) and strikes N. 20° W. Overlying the limestone is a 3-m thick black shale that is also part of the limestone member. Orange-brown-weathering sandstone with olive-gray shale interbeds represents the Terra Cotta Mountains Sandstone and stratigraphically overlies the Post River Formation here. The structure in the Terra Cotta Mountains Sandstone consists of a tightly folded syncline, apparently faulted on its western limb, and another syncline to the west that contains argillaceous rocks and mudstone from which a sparse graptolite fauna was collected. This collection (pl. 2, colln. site 70ACn22) is approximately early to middle Ludlovian in age and is therefore considerably younger than the Early Silurian graptolites in the limestone member of the Post River Formation.

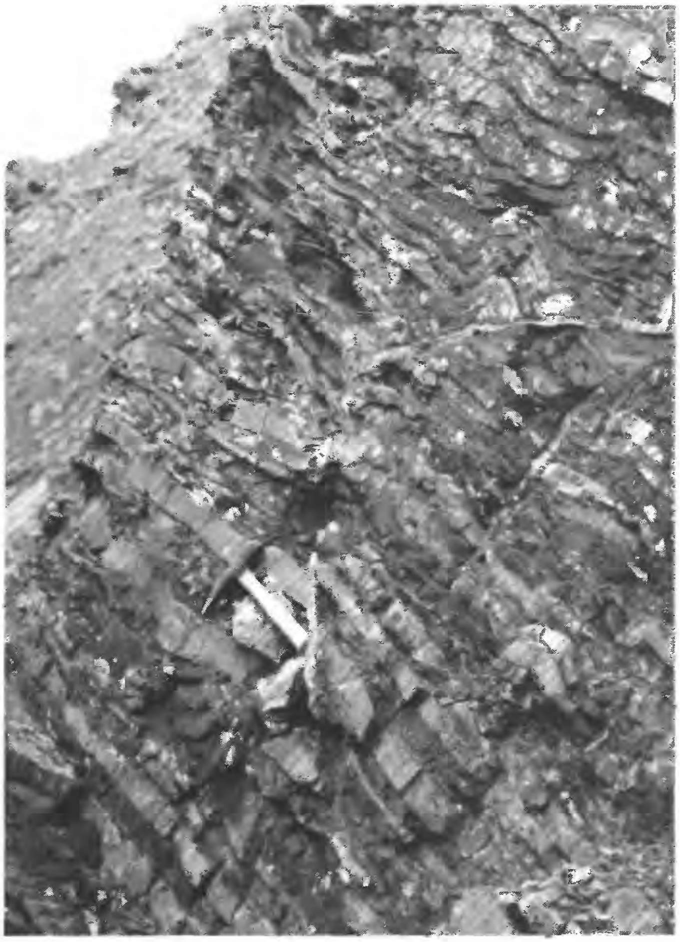


Figure 20. Tightly folded, thinly interbedded, calcareous siltstone and phyllitic shale of upper part of lower siltstone member of Post River Formation, Terra Cotta Mountains, Alaska. Beds are mostly 2 to 5 cm thick, with some thickening of beds in crests of folds. Siltstone beds are crosslaminated and medium light gray, weathering to yellowish orange. Some very rare pure limestone beds weather medium gray and are finely crystalline. Argillaceous beds make up 30 to 40 percent of the section and generally are platy, breaking into fragments 3 to 6 mm thick. Small folds trend N. 15° W. and plunge 15° N. This structure represents eastern, right-side-up limb of Terra Cotta Anticline. Folds are asymmetrical, with steeper and shorter limbs on the west (left in photograph). Near-vertical cleavage surfaces with phyllitic sheen appear to be axial-plane cleavage. About 15 m above this outcrop is contact between lower siltstone member and overlying mudstone member of Post River Formation. Outcrop is several hundred meters west of Camp #2 1969 (pl. 2), at elevation 4,500 ft, on western flank of Terra Cotta Mountains, NW1/4 sec. 7, T. 24 N., R. 23 W. (between cross sections *H-I* and *J-K* on pl. 1).

Figure 21. Sheared contact between lower siltstone member (Opls) and mudstone member (Opm) of Post River Formation. Craggy, light-colored outcrops to the right (east) are overturned and dipping east. Dark-gray, smooth slopes in center and to left (west) are the overlying mudstone member. Overturned contact dips east, and shows evidence of shear and thrust faulting. Irregular resistant outcrops at center are multiple crosscutting igneous dikes. Photograph taken from collection site 69ACn482 (pl. 2), looking north along western, overturned limb of Terra Cotta Anticline.

SECTION *J-K-L-M*

This section crosses the southern end of the Terra Cotta Mountains (pl. 1). It begins on the west in the overturned limb of the Terra Cotta Anticline, crosses the axis of the anticline, which forms the rugged western slope of the mountains, and intersects the measured type section of the Post River Formation (pls. 2, 3*B*). At the crest of the mountains, the section crosses a narrow syncline capped by the Terra Cotta Mountains Sandstone and a poorly exposed anticline within the Graptolite Canyon Member of the Post River Formation. Farther east the section crosses the Terra Cotta Mountains Sandstone, revealing its limestone members within the predominantly siliciclastic section. The cross section continues down the east side of the mountains across slopes that are covered by mainly carbonate rubble of the Barren Ridge Limestone.

This section traverses all of the units in the map area, but, because it is oriented mainly along the ridge tops, it does not include some of the best exposures, which are located along creeks and canyons. Nevertheless, more than 18 fossil collections, all but one of which are graptolite collections, were made on or close to this structure section (pl. 2). Penetrative cleavage, especially in argillaceous units, countless sheared surfaces, and numerous fault offsets on a scale of a few centimeters or meters were observed along the structure section. The apparent strike of the upper siltstone member of the Post River Formation into the limestone member or into the basal sandstone member of the Terra Cotta Mountains Sandstone about 1 km north of the cross section indicates that faulting cuts out all or most of the Graptolite Canyon Member. Another fault may separate the uppermost part of the Terra Cotta Mountains Sandstone from the overlying Barren Ridge Limestone. This contact, although mostly covered, appears to swing across the strike of beds and may represent a major fault. Furthermore, carbonate breccia observed about 0.5 km east of Peak 5110 may represent a fault breccia that indicates another important fault paralleling the lithologic units within the Terra Cotta Mountains Sandstone.

Details of structure and stratigraphy along section *J-K-L-M* are discussed below from west to east. On the western flank of the Terra Cotta Mountains, east of point *J* (pl. 1), the section starts in dark-gray siliceous shale of the Graptolite Canyon Member that is cut by a felsic igneous sill too small to map. Directly east of the shale, beds of very fine grained calcareous sandstone with phyllitic partings strike due north and dip 10° E. Intricate crosslaminations and load casts indicate that the beds are overturned; they appear to be thrust westward over the purer, dark shale section. These sandy beds represent a horizon near the top of the lower siltstone member of the Post River Formation. Several hundred meters farther east in the first saddle is a lithologically similar, very thin bedded section of calcareous sandstone, siltstone, silty limestone, and minor, nearly pure, micritic limestone. Rare specimens of *Araneograptus*? are preserved in the argillaceous layers, and worm casts are common. Isoclinal folds in isolated outcrops have fold axes that trend N. 5° E. and plunge 15° N. Axial planes of the folds are subhorizontal or dip as much as 25° eastward. This section of the lower siltstone member of the Post River Formation forms the axial part of the Post River Anticline. It weathers into yellowish-brown slopes that contrast with the orange-brown slopes underlain by the stratigraphically higher Terra Cotta Mountains Sandstone. To the east and a few hundred meters lower in the siltstone member is graptolite locality 69ACn501 (pl. 1, section *J-K-L-M*, loc. a; pl. 2) in calcareous siltstone which contains a few unidentified branched graptolites that were not collected. This lithology persists across the axis of the anticline, which itself is isoclinally folded internally. A dark-gray silty shale or mudstone bearing a *Tetragraptus approximatus*-Zone fauna directly overlies the lower siltstone member. The contact between this mudstone interval and the lower siltstone member is accordant but cut in places by cross faults trending eastward, with a few centimeters to a few meters of displacement. These appear to be high-angle faults developed perpendicular to the main, northerly fold axis of the Post River Anticline.

The cross section continues eastward through the cliff exposures that constitute the type section of the Post River Formation, up to a small, canoe-shaped syncline that exposes the overlying Terra Cotta Mountains Sandstone (pl. 1). The shape of the syncline is well defined by a thin-bedded limestone (the limestone member of the Post River Formation) with soft, black, graptolitic shale partings that overlies the Graptolite Canyon Member.

Overlying the limestone and forming the center of the syncline is calcareous sandstone and argillite of the Terra Cotta Mountains Sandstone. The argillite is strongly cleaved into pencil-like rods. Any graptolites that may have been on the bedding planes have been destroyed. East of the syncline (pl. 1) an interval of about 0.5 km is mainly covered by dark-gray graptolitic shale of the Graptolite Canyon Member. About five separate graptolite localities across this interval indicate an anticlinal structure; the faunas range in age from Early Silurian on the west flank of the fold to Middle Ordovician near the axis. The cross section next crosses steeply dipping beds of the upper siltstone member and then siliceous shale beds containing a graptolite fauna of the *Climacograptus bicornis* Zone (pl. 2, colln. site 70ACn212). About 100 m farther east are good outcrops of the limestone member of the Post River Formation, which strikes N. 10° E., dips 70° E., and contains a Llandoverian graptolite fauna (colln. site 70ACn532).

A thick unit of 20- to 60-cm beds of calcareous sandstone with argillitic interbeds less than 0.3 m thick directly overlies the limestone member. The argillite is strongly cleaved into thin, pencil-like fragments. This lowest sandstone and mudstone interval in the Terra Cotta Mountains Sandstone is overlain by about 22 to 30 m of medium-thick-bedded limestone of the lower limestone member. Two micaceous, silty, argillitic shale and siltstone units, each about 1.5 m thick, occur in the middle part of this carbonate unit. The cross section next crosses dark-gray argillitic shale and subordinate fine-grained sandstone. This sandstone has little matrix, is highly calcareous, and is a quartzose arenite that grades to silty and sandy limestone in some beds. This second interval of mainly sandstone in the Terra Cotta Mountains Sandstone is overlain by the middle limestone member, which strikes northward and dips 65° E. The middle limestone member, especially in its lower part, is laminated and platy, and here it contains poorly preserved shelly fossils. Where the lower part of the middle limestone member is laminated, it is also internally folded. Higher in the section, the middle limestone member is more massive and weathers a lighter medium gray. Near its top, it is silty, micaceous, crosslaminated, platy, and orange weathering. The middle limestone member is overlain by another calcareous sandstone and sandy limestone interval that includes orange-weathering, knobby limestone that forms a prominent marker bed farther north in Graptolite Canyon. About 15 m stratigraphically above the top of the middle limestone member, graptolites of the *Monograptus ludensis* Zone were found in shale float at collection site 70ACn552 (pl. 2; fig. 4). The slabs of shale float have a micaceous sheen and are associated with fine-grained sandstone.

Cross section *J-K-L-M* shows the general succession of lithologies between the middle and upper limestone members of the Terra Cotta Mountains Sandstone. At point *L*, the upper limestone member is exposed in Peak 5110, where massive and thick-bedded layers average 0.6 m thick. In places, the limestone beds are thinner, and some rare platy or slabby limestone is also present. It is medium dark gray and weathers medium gray. Closely spaced, very fine veinlets of calcite cut the limestone so that it readily breaks into pebble-size fragments when hit with a hammer. This part of the upper limestone member is characterized by its purity and apparent lack of argillaceous or silty and sandy beds.

From Peak 5110, the section follows a dip slope to the bottom of Graptolite Canyon (pl. 1). A series of dikes occurs at the contact between the upper limestone member and the predominantly calcareous sandstone, siltstone, and occasional limestone that forms the uppermost interval of the Terra Cotta Mountains Sandstone. The interval forms brownish- and yellowish-orange-weathering outcrops and talus. The beds are mainly thin (1.3 to 5 cm) and split into slabby pieces. The rarer, purer limestone interbeds are medium dark gray and contain thin argillite interbeds that have a phyllitic sheen and are olive gray in color.

In the saddle about 0.5 km due east of Peak 5110 is a unique bed of limestone edgewise conglomerate about 1.8 m thick. This coarse-clastic rock type is composed of polymictic limestone clasts and some pebbles and granules of dark-gray chert and siliceous shale in a matrix of siliciclastic siltstone and sandstone. The matrix is more resistant to weathering than are the larger limestone clasts. Orange-weathering sandstone and siltstone fragments also occur in the conglomerate. The clasts are poorly sorted. Some of the limestone clasts are as much as 30 cm across. The chert fragments are generally angular to subangular. In places, the conglomerate is more nearly breccia. Beds above and below this conglomerate are thin-bedded limestone, calcareous sandstone, and siltstone. The limestone beds typically form lenses parallel to bedding. These beds strike N. 30° W. and dip 40° E., and crosslaminations in the sandy beds indicate that the beds are right side up.

Higher in the section is a massive sandstone that weathers orange. The beds are about 1 m thick and grade from coarse sandstone at the base to slabby limestone with argillaceous interbeds at the top. The sandstone is composed of subangular sand grains of dark chert and quartz. Generally, it has little matrix material, and fine-grained layers are calcareous. Shale chips and platy clasts of limestone are rarely present.

The lower slopes are mostly covered, but at about 4,000 ft elevation there is perceptibly more limestone; a dashed and probably faulted contact is drawn here to separate the Post River Formation from the overlying lower limestone member of the Barren Ridge Limestone.

GRAPTOLITE FAUNA OF THE TERRA COTTA MOUNTAINS

By Claire Carter

INTRODUCTION

In 1967, during the course of field work in the Terra Cotta Mountains of central Alaska (fig. 1), Bruce Reed and Rod May discovered graptolites. Subsequently, Michael Churkin, Jr., and several associates collected extensively in the area. They made 41 graptolite collections at varying intervals in a measured section approximately 330 m thick (pl. 3*B*), and another 75 collections at various localities in the area from isolated outcrops or float (pl. 2). The latter are hereafter referred to as the scattered collections.

It is rare to find a number of graptolite zones together in an unbroken stratigraphic succession, as in the Terra Cotta Mountains section. Graptolite zones as old as Tremadocian and as young as Wenlockian can be recognized from the faunas of the Post River Formation and the Terra Cotta Mountains Sandstone. The zones in the measured section are established on the faunas actually present in the Post River Formation and have been given the same names as zones elsewhere with which they may be most closely correlated.

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ORDOVICIAN GRAPTOLITE ZONES AND CORRELATIONS

Some of the Ordovician graptolite zones in the Terra Cotta Mountains are herein established on the faunas present in the measured section (pl. 3*B*). These include the *Tetragraptus approximatus, T. fruticosus, Diplograptus*? *decoratus, Dicellograptus, Climacograptus bicornis,* and *C. tubuliferus* Zones. The remainder of the Ordovician (and Silurian) zones described below represent faunas from scattered localities instead of from an orderly stratigraphic sequence and have been correlated with Ordovician (and Silurian) zones established elsewhere (figs. 22 and 23).

Adelograptus ZONE

Three of the scattered collections (table 1) are correlated with Cooper's (1979) Zone of *Adelograptus*, (fig. 22) because of the presence of *Temnograptus*? sp., *Adelograptus*? aff. *A. antiquus* (T.S. Hall), and *Araneograptus*? *murrayi* (Hall), which resembles the New Zealand form, *A. pulchellus* T.S. Hall. The fauna in these three collections is sparse, and the specimens are fragmentary and not well preserved, but their occurrence at a lower stratigraphic level than the first appearance of *Tetragraptus approximatus* Nicholson gives weight to their assignment to the *Adelograptus* Zone.

Cooper (1979) correlated his *Adelograptus* Zone with the *Adelograptus-Clonograptus* Zone of Texas (Berry, 1960), with the middle Lancefieldian Zone (La2) of Australia, and with the upper part of the Tremadocian Stage of Britain.

Tetragraptus approximatus ZONE

Three collections at the base of the measured section (table 2) and one of the scattered collections (table 1) represent this zone and are tentatively correlated with Cooper's (1979) Zone of *T. approximatus*, on the basis of the occurrence of the name-giving species. All of these collections are small and contain only a single species apiece; they lack the *Adelograptus* and *Clonograptus* of the New Zealand zone.

The *T. approximatus* Zone has been described from western Canada (Lenz and Jackson, 1986) and Texas (Berry, 1960). In all of these places, *T. approximatus* first appears in the *T. approximatus* Zone, and in Texas it is restricted to this zone, although it does range higher in New Zealand and Canada.

Tetragraptus fruticosus ZONE

One collection in the measured section (table 2) and three of the scattered collections (table 1) represent this zone and are correlated with Cooper's (1979) Zone of *T. fruticosus*. The Terra Cotta Mountains fauna lacks the *Sigmagraptus, Trichograptus* and *Dichograptus* that occur in the zone in New Zealand, but it does contain the important 3- and 4-branched *T. fruticosus* (Hall), *Goniograptus macer* T.S. Hall, *Phyllograptus* cf. *P. angustifolius angustifolius* Hall, *P. anna* Hall, *Didymograptus extensus* (Hall), and *D.* cf. *D. ensjoensis* Monsen, as well as *T. quadribrachiatus* (Hall) and *T.* cf. *T. serra* (Brongniart). The Terra Cotta Mountains fauna can also be correlated with the Zone of *T. fruticosus* in western Canada (Lenz and Jackson, 1986) and Texas (Berry, 1960) on the basis of the above-listed species. As in western Canada (Lenz and Jackson, 1986), Berry's (1960) subdivision of the *T. fruticosus* Zone based on the presence of 3- and 4-branched forms of *T. fruticosus* is not recognizable in the Terra Cotta Mountains section.

The measured section is barren of graptolites for approximately the next 50 m (see pl. 3*B*), and faunas correlative with the intervening zones of the New Zealand succession, namely the *Didymograptus protobifidus, Isograptus victoriae lunatus, I. v. maximodivergens, Oncograptus,* and *Paraglossograptus tentaculatus* Zones, have not been found. However, faunas representing the *Oncograptus* and *P. tentaculatus* Zones have been collected at other localities in the Terra Cotta Mountains.

Oncograptus ZONE

Four of the scattered collections have been correlated with Cooper's (1979) Zone of *Oncograptus* on the basis of the presence of ?*Apiograptus* ?*crudus* (Harris and Thomas), *Pseudotrigonograptus* sp., *Isograptus* cf. *I. forcipiformis* (Ruedemann), *I.* cf. *I. victoriae divergens* Harris, *I.* cf. *I. v. maximodivergens* Harris, *Pseudisograptus* cf. *P. jiangxiensis* (Yu and Fang), and *P. manubriatus janus* Cooper and Ni. Important taxa missing from the Terra Cotta Mountains collections include *Oncograptus* and *Cardiograptus*, but the presence of *P.* cf. *P. jiangxiensis* and *P. manubriatus janus*, which are restricted to this zone in New Zealand, strongly suggest correlation with the *Oncograptus* Zone.

Oncograptus and *Cardiograptus* are similarly absent from the *Oncograptus* Zone in the northern Canadian Cordillera (Lenz and Jackson, 1986) and from the *Oncograptus* Zone in the Baird Mountains section 650 km to the northwest in the Brooks Range (Carter and Tailleur, 1984).

Paraglossograptus tentaculatus ZONE

This zone was not found in the measured section (pl. 3*B*) but is represented by four of the scattered collections. The faunas of these four collections are somewhat sparse and show no predominant taxa, but they are assigned to this zone on the basis of comparison with Cooper's (1979) faunal list for his *P. tentaculatus* Zone. As in New Zealand, this zone marks the first appearance of *Glyptograptus* and the last appearance of *Tetragraptus* and *Isograptus* in the section. *P. tentaculatus* (Hall) is restricted to this zone.

Diplograptus? decoratus ZONE

This zone is established on graptolites from seven collections over an approximately 30-m interval above 50 m of barren siltstone and mudstone in the measured section (pl. 3*B*). Four of the scattered collections (table 1) can also be correlated with this zone. The most characteristic species, which occurs throughout the zone, is *Climacograptus riddellensis* Harris. The lower part of the zone is also characterized by the presence of *Pterograptus* cf. *P. elegans* Holm, *Cryptograptus schaeferi* Lapworth, *Phyllograptus nobilis* Harris and Keble (in the scattered collections), and *Glossograptus ciliatus* Emmons. The upper part of the zone largely lacks *G. ciliatus* and *C. schaeferi* and completely lacks *Phyllograptus* and *Pterograptus*. Glyptograptids of one species or another are common throughout the zone: *G. euglyphus* (Lapworth), *G.* sp. aff. *G. dentatus* (Brongniart), *G. shelvensis* Bulman, *G.* spp. *D.*? *decoratus* is rare but occurs with faunas typical of both lower and upper parts of the zone.

The Terra Cotta Mountains *D.*? *decoratus* Zone correlates extremely well with Cooper's (1979) *D.*? *decoratus* Zone in New Zealand except for the occurrence of *P. nobilis,* which does occur in the *D.*? *decoratus* Zone (Da3) in Australia (Berry, 1966). It correlates approximately with Lenz and Jackson's (1986) upper *P. tentaculatus* Zone in the Canadian Cordillera on the basis of *D.*? *decoratus, C. riddellensis*, and *C. schaeferi* and the absence of dicellograptids

Stage	Marathon Region, Texas Berry, 1960	Trail Creek, Idaho Carter and Churkin, 1977	Northwestern Canada Lenz and Chen, 1985 Lenz and Jackson, 1986	New Zealand Cooper, 1979	Terra Cotta Mountains, Alaska This paper
Ashgillian	*Dicellograptus ornatus*	*D. ornatus*	*D. ornatus*		
Caradocian	*Orthograptus quadrimucronatus*	*Pleurograptus linearis*	*O. quadrimucronatus*		
	O. amplexicaulis	*Climacograptus tubuliferus*	*Dicranograptus clingani*		*C. tubuliferus*
		"Passage beds"			
	C. bicornis	*C. bicornis*	*Climacograptus bicornis*		*C. bicornis*
Llandeilan	*Nemagraptus gracilis*	*Nemagraptus*	*N. gracilis*	*Dicellograptus*	*Dicellograptus*
Llanvirnian	*Glyptograptus* cf. *G. teretiusculus*	*Glossograptus hincksii*	*Glyptograptus euglyphus* *Diplograptus ? decoratus*	*D.? decoratus*	*D.? decoratus*
Arenigian	*Paraglossograptus tentaculatus*		*Paraglossograptus tentaculatus*	*P. tentaculatus*	*P. tentaculatus*
	Isograptus caduceus	*Isograptus*	*Oncograptus*	*Oncograptus*	*Oncograptus*
		Didymograptus protobifidus	*I. victoriae maximodivergens*	*I. v. maximodivergens*	
	Didymograptus bifidus		*I. v. lunatus*	*I. v. lunatus*	
	D. protobifidus		*D. protobifidus*	*D. protobifidus*	
	Tetragraptus fruticosus		*T. fruticosus*	*T. fruticosus*	*T. fruticosus*
	T. approximatus		*T. approximatus*	*T. approximatus*	?*T. approximatus*
Tremadocian	*Adelograptus–Clonograptus*			*Adelograptus*	*Adelograptus*

Figure 22. Correlation of Ordovician graptolite sequences in Texas, Idaho, Canada, New Zealand, and Alaska.

and dicranograptids, but it lacks the Canadian zone's abundant sinograptids. The Texas Zone of *G.* cf. *G. teretiusculus* (Berry, 1960) contains *C. riddellensis*, *G.* cf. *G. teretiusculus* (Hisinger), and *P. nobilis* in common with the Terra Cotta Mountains *D.*? *decoratus* Zone and similarly lacks dicellograptids and dicranograptids, suggesting a correlation of the two zones.

Dicellograptus ZONE

This zone marks the first appearance of *Dicellograptus* and *Dicranograptus* in the Terra Cotta Mountains succession. It comprises six graptolite collections in approximately 25 m of siliceous mudstone and shale in the measured section and is bounded by a fault at its upper limit. The presence of various species of *Dicellograptus* and *Dicranograptus* and the absence of most of the characteristic species of the underlying *D.*? *decoratus* Zone serve to distinguish this zone. As in Australia and New Zealand (Cooper, 1979, p.46), the first dicellograptids in the sequence appear significantly earlier than does *Nemagraptus gracilis* (Hall). Indeed, the only nemagraptid in the Terra Cotta Mountains *Dicellograptus* Zone is a single proximal fragment of *Nemagraptus*? sp. that occurs well above the base of the zone.

The Terra Cotta Mountains *Dicellograptus* Zone correlates well with the *Dicellograptus* Zone of New Zealand (Cooper, 1979) and with the *N. gracilis* Zone of Texas (Berry, 1960), on the basis of the first appearance of *Dicellograptus* and *Dicranograptus,* although the Alaskan zone lacks *N. gracilis, C. riddellensis, Pseudoclimacograptus, Glossograptus,* and *Leptograptus*, all of which are found in the Texas zone.

Climacograptus bicornis ZONE

Approximately 35 m of siliceous shale in the measured section (12 collections) and 14 scattered collections have been assigned to this zone. The lowest collection of *C. bicornis*-Zone graptolites in the measured section (69ACn554, pl. 3*B*) occurs just above one collection (69ACn553) representing the next higher *Climacograptus tubuliferus* Zone in an interval that occurs above a fault, so the location of the base of the *C. bicornis* Zone is uncertain. The *C. bicornis* Zone is characterized by the presence of *Cryptograptus tricornis* (Carruthers), *Climacograptus bicornis bicornis* (Hall), and *Amplexograptus fallax* Bulman, which occur in nearly every collection in the zone but not in the underlying *Dicellograptus* Zone. In addition, *Lasiograptus*, *Leptograptus,* various large orthograptids, and several species of *Dicranograptus* make their first appearance in the *C. bicornis* Zone.

The Terra Cotta Mountains *C. bicornis* Zone correlates well with Berry's (1960) *C. bicornis* Zone in Texas. In addition, it contains elements of Berry's *Nemagraptus gracilis* Zone (*Dicranograptus brevicaulis* Elles and Wood, *D. contortus* Ruedemann, *N. gracilis*). The *C. bicornis* Zone at Trail Creek, Idaho (Carter and Churkin, 1977) also correlates well with the Terra Cotta Mountains *C. bicornis* Zone.

Climacograptus tubuliferus ZONE

About 60 m of the measured section (pl. 3*B*), 16 m of which are thin beds of ungraptoliferous shale and mudstone, are included in the *C. tubuliferus* Zone. Seven graptolite collections were made from this zone in the measured section, in addition to one from the base(?) of the *C. bicornis* Zone, but only one of the scattered collections is from this zone. *Climacograptus spiniferus* Ruedemann and *C. caudatus* Lapworth first appear at the base of the zone, while *C. tubuliferus* Lapworth occurs in the middle and upper parts of the zone. It is also characterized by the presence of *Orthograptus amplexicaulis amplexicaulis* (Hall). Dicranograptids are very rare, in contrast with the underlying *C. bicornis* Zone, and dicellograptids are sparse.

The Terra Cotta Mountains *C. tubuliferus* Zone is correlated with the Trail Creek, Idaho, *C. tubuliferus* Zone (Carter and Churkin, 1977) on the basis of the presence in both of *Dicellograptus alector* Carter, *C. caudatus*, *C. tubuliferus*, and *O. amplexicaulis amplexicaulis*. It is correlated with the Texas Zone of *O. amplexicaulis* (=*O. truncatus* var. *intermedius*; Berry, 1960), because of the presence of *C. caudatus*, *C. spiniferus*, and *O. amplexicaulis amplexicaulis*, and also with part of the next higher *O. quadrimucronatus* Zone, because of the presence of *C. tubuliferus*. It includes species indicative of the early Eastonian of Australia (*C. spiniferus*, *C. caudatus*) as well as those indicative of the late Eastonian (*C. tubuliferus*, *D. alector*=*D. gravis* Keble and Harris) (VandenBerg, 1981).

SILURIAN GRAPTOLITE ZONES AND CORRELATIONS

All of the Silurian collections, with one exception (table 2), are from isolated outcrops instead of from a stratigraphic sequence. Therefore, it has not been possible to establish a local zonal succession for the Silurian. Instead, the individual collections have been correlated with the standard British succession as described by Rickards (1976) and Hutt (1974; 1975), at least up through the *Monograptus turriculatus* Zone (fig. 23). For the late Llandoverian, the western Canadian zones of *M. spiralis* and *Cyrtograptus sakmaricus*–*C. laqueus* (Lenz, 1979; 1982) seem to be more applicable to the Terra Cotta Mountains section (fig. 23). For the Wenlockian and Ludlovian, we must return to the British zonal scheme. Most of the zonal assignments are fairly straightforward; some of the collections, however, have been more difficult to correlate due to sparse faunas of undiagnostic species (for example, collections 70ACn232a, b and 70ACn532 on table 3) or due to mixing in a float collection (70ACn423; table 3).

Lagarograptus acinaces and *Coronograptus cyphus* ZONES

One collection (table 3) is correlated with this interval because of the presence of *Climacograptus innotatus innotatus* Nicholson, *Cystograptus vesiculosus* (Nicholson), *Atavograptus strachani* (Hutt and Rickards), *Coronograptus cyphus* (Lapworth) and *Lagarograptus* cf. *L. tenuis* (Portlock).

Monograptus convolutus ZONE

Two collections (table 3) are correlated with the *M. convolutus* Zone because they contain *Cephalograptus tubulariformis* (Nicholson), *Monograptus clingani* (Carruthers), *M. convolutus* (Hisinger), and *M. undulatus* Elles and Wood, all of which are restricted to this zone in the British succession, and *Glyptograptus incertus* (Elles and Wood), which first appears in the *M. convolutus* Zone (Rickards, 1976).

Monograptus sedgwickii ZONE

A single collection of mixed float (70ACn423; table 3) contains elements of the *M. convolutus* Zone and the *M. turriculatus* Zone, but it is mainly composed of species indicative of the *M. sedgwickii* Zone, including *M. sedgwickii* (Portlock).

Monograptus turriculatus ZONE

Five collections (table 3) are included in the *M. turriculatus* Zone on the basis of the presence of *Petalograptus palmeus palmeus* (Barrande), *M. turriculatus* (Barrande), *M. exiguus* (Nicholson), *M. runcinatus runcinatus* Lapworth, and *M. decipiens valens* (Přibyl and Münch), all of which make their first in situ appearance in this zone. Lenz's (1982) practice of regarding the *Rastrites maximus* Zone as a subzone

Stage	Northwestern Canada Lenz, 1979,1982	British Isles Rickards, 1976	Terra Cotta Mountains, Alaska This paper
Ludlovian		*Pristiograptus tumescens* *Lobograptus scanicus* *Neodiversograptus nilssoni*	
Wenlockian		*Monograptus ludensis*	approx. *M. ludensis*
		Gothograptus nassa	*M. digitatus*
		Cyrtograptus lundgreni	*C. lundgreni*
		Cyrtograptus ellesae *Monograptus flexilis* *Cyrtograptus rigidus* *Monograptus riccartonensis* *Cyrtograptus murchisoni*	
		Cyrtograptus centrifugus	*C. centrifugus*
Llandoverian	*Cyrtograptus sakmaricus–* *C. laqueus*	*M. crenulata* *M. griestonensis* *M. crispus*	*C. sakmaricus–* *C. laqueus*
	M. spiralis		*M. spiralis*
	M. turriculatus	*M. turriculatus* *Rastrites maximus*	*M. turriculatus*
	M. sedgwickii	*M. sedgwickii*	*M. sedgwickii*
	M. convolutus	*M. convolutus*	*M. convolutus*
	M. argenteus *Diplograptus magnus* *M. triangulatus*	*M. leptotheca* *Diplograptus magnus* *M. triangulatus*	
	M. gregarius *Lagarograptus acinaces*	*Coronograptus cyphus* *L. acinaces*	*L. acinaces–* *C. cyphus*
	Atavograptus atavus *Orthograptus acuminatus* *Glyptograptus persculptus*	*A. atavus* *O. acuminatus* *G. persculptus*	

Figure 23. Correlation of Silurian graptolite sequences in Canada, the British Isles, and Alaska.

(herein unrecognizable) of the *M. turriculatus* Zone is followed here.

Monograptus spiralis ZONE

Seven collections (table 3) have been assigned to this zone (see Lenz, 1979; 1982). The presence of *M. spiralis* Geinitz, *M.* cf. *M. priodon* (Bronn), *Retiolites geinitzianus geinitzianus* Barrande, *R. geinitzianus angustidens* Elles and Wood, and *Diversograptus ramosus* Manck, combined with the absence of species characteristic of the underlying *M. turriculatus* Zone and the lack of *Cyrtograptus,* which generally first appear in the overlying *C. sakmaricus–C. laqueus* Zone, indicate correlation with the *M. spiralis* Zone.

Cyrtograptus sakmaricus–C. laqueus ZONE

Five collections (table 3) are correlated with the Canadian *C. sakmaricus–C. laqueus* Zone of Lenz (1979; 1982), based mainly on the presence of cyrtograptids (*C. sakmaricus* Koren', *C.* cf. *C. lapworthi* Tullberg, *C.* sp. aff. *C. lundgreni* sensu Lenz).

Cyrtograptus centrifugus ZONE

One collection (table 3) containing an unnamed species of *Monograptus, Monoclimacis* sp., *Retiolites*? sp., and *Barrandeograptus*? *bornholmensis* (Laursen), has been correlated with the *C. centrifugus* Zone, primarily on the basis of the presence of *B.*? *bornholmensis,* which occurs in the *C. centrifugus* Zone at Bornholm, Denmark (Bjerreskov, 1975).

Cyrtograptus lundgreni ZONE

Two collections (table 3) are correlated with the *C. lundgreni* Zone, mainly on the basis of the presence of *C.* cf. *C. mancki* Bouček. *C. mancki* s.s. occurs in the *Monograptus testis–C. lundgreni* Zone of northern Canada (Lenz, 1978) and in the *C. lundgreni* Zone in Europe (Rickards and others, 1977, text-fig. 42).

Monograptus digitatus ZONE

This zone is recognized only in the Terra Cotta Mountains and is represented by five collections (table 3). In these collections, the main element of the fauna is a previously unknown form, *M. digitatus* n. sp. Because its associated forms—*Pristiograptus* cf. *P. pseudodubius* (Bouček), *Monograptus* cf. *M. uncinatus micropoma* (Jaekel), *Gothograptus* sp.—are not abundant, distinctive, or readily identifiable, the correlation of this interval with the British zonal scheme (Rickards, 1976) is uncertain. This zone occurs stratigraphically below the *M. ludensis* Zone faunas and, on the basis of its fauna, appears to fall a little below the Wenlockian-Ludlovian boundary.

Monograptus ludensis ZONE

Six collections (table 3) have been tentatively assigned to the *M. ludensis* Zone because of the presence of *M.* cf. *M. ludensis* (Murchison) sensu Wood, *Pristiograptus* cf. *P. jaegeri* Holland, Rickards, and Warren, and *Holoretiolites* (*Balticograptus*) cf. *H.* (*B.*) *lawsoni* Holland, Rickards, and Warren, all of which (sensu stricto) are restricted to the *M. ludensis* Zone in the British succession (Rickards, 1976).

EARLY LUDLOVIAN

The youngest graptolite fauna collected in the Terra Cotta Mountains consists of *Bohemograptus bohemicus* (Barrande) and *Monograptus* sp., indicative of the *Neodiversograptus nilssoni* through *Pristiograptus tumescens* Zones in the British succession (Rickards, 1976), although *Bohemograptus* does range higher in Poland (Rickards and others, 1977).

SYSTEMATIC DESCRIPTIONS

Most of the graptolites from the Terra Cotta Mountains, particularly those from the Graptolite Canyon Member of the Post River Formation, are preserved as flattened, silvery or whitish films on dark shale. Many of the graptolites from the mudstone member of the Post River Formation are preserved as three-dimensional internal molds that have weathered brown to orange on the rough bedding planes characteristic of the mudstone member; the rest are silvery and flattened. Specimens from the Terra Cotta Mountains Sandstone are dark brown to nearly black and are flattened on bedding planes of lighter colored, olive-brown argillite or mudstone. Most of the specimens exhibit little or no tectonic distortion; where present, distortion is noted in the individual species descriptions that follow.

The terminology and classification used herein are mainly from Bulman (1970). Mitchell (1987) has proposed a revolutionary reclassification of the Diplograptacea, but determining astogeny with flattened specimens is very difficult and well beyond the scope of this paper. Therefore, I have retained the old form genera and left the reclassification for workers who have more suitable material. The synonymies are not always exhaustive but instead represent, for the most part, only those citations with which I am personally acquainted. The repository of all the specimens bearing a USNM number is the U.S. National Museum of Natural History, Smithsonian Institution, Washington, D.C. Specimens designated UA are in the University of Alaska (Fairbanks) Museum and were collected from the Windy Fork area, McGrath A-2 quadrangle.

Class GRAPTOLITHINA Bronn, 1846
Order DENDROIDEA Nicholson
Family ANISOGRAPTIDAE Bulman, 1950
Subfamily CLONOGRAPTINAE Erdtmann, 1982
Genus *Araneograptus* Erdtmann and VandenBerg, 1985
***Araneograptus*? *murrayi* (Hall)**

Figure 24*C*

Dictyonema murrayi Hall, 1865, p. 138, pl. 20, figs. 6, 7. Ruedemann, 1904, p. 606, pl. 3, fig. 12. Ruedemann, 1947, p. 171, pl. 4, figs. 15, 16; pl. 10, fig. 1.

Diagnosis.—Rhabdosome very large, of unknown shape. Stipes about 1.5 mm wide, separated by slightly wider interspaces. Transverse dissepiments straight and rigid, about 3 mm apart. Thecae, 9 to 10 per centimeter.

Discussion.—Erdtmann and VandenBerg (1985) compared "*Dictyonema*" *murrayi* to species of their new genus *Araneograptus*, but, because the proximal development of *murrayi* is not known, they declined to refer it to *Araneograptus* at that time. *A.*? *murrayi* resembles "*D.*" *grande* Nicholson, but the spaces between the stipes differ; they are noticeably longer than wide in *A.*? *murrayi* and the reverse in "*D.*" *grande*. *A. pulchellus* is very similar in appearance to *murrayi* but differs in dimensions.

Occurrences.—Collection 69ACn482; *Adelograptus* Zone. The lower shales of the Quebec Group, Pt. Levis, Quebec (Hall, 1865).

Order GRAPTOLOIDEA Lapworth, 1875
Family DICHOGRAPTIDAE Lapworth, 1873, sensu lato
Genus *Brachiograptus* Harris and Keble, 1932
***Brachiograptus etaformis* Harris and Keble**

Figures 24*A*, *D*, *E*

Brachiograptus etaformis Harris and Keble, 1932, p. 44, pl. 6, figs. 8, 9. Berry, 1960, p. 50.

Loganograptus logani mut. *pertenuis* Ruedemann. Ruedemann, 1947, pl. 45, figs. 15, 16 (not fig. 14). Lenz and Jackson, 1986, fig. 5E.

Diagnosis.—Sicula small, funicle 2 mm long. Second-order dichotomous branches diverge at angles of 105° to 130°, forming H-shaped rhabdosome. Third-order branches arise usually from first 2 or 3 thecae of each second-order branch. Thecae slender, 8 to 10 per centimeter.

Discussion.—*Brachiograptus* is distinguished from *Loganograptus* mainly by the fact that its third-order stipes are unbranched. The Alaskan specimens have only 2 third-order branches on each second-order stipe, and the maximum width of their stipes is 0.5 mm.

Occurrences.—Collections 69ACn391 and 70ACn192; *Paraglossograptus tentaculatus* Zone. Upper Darriwilian (Da3; *Diplograptus*? *decoratus* Zone) in Victoria, Australia (Harris and Keble, 1932; VandenBerg, 1981). The Glenogle Shale in British Columbia, Canada, and the Blakely Sandstone in Arkansas (Ruedemann, 1947). The *P. tentaculatus* Zone (*Hallograptus etheridgei*) in Texas (Berry, 1960) and in northwestern Canada (Lenz and Jackson, 1986).

Genus *Pterograptus* Holm, 1881
***Pterograptus* cf. *P. elegans* Holm**

Figures 25*A*–*C*, *E*

cf. *Pterograptus elegans* Holm, 1881, p. 77–80, figs. 1–4. Benson and others, 1936, p. 380–381, figs. 5a–c. Berry, 1964, p. 82–84, pl. 1, figs. 1, 3. Wang and Jin, 1977, p. 281, pl. 86, figs. 2, 3.

Description.—The sicula is 0.75 to 1.0 mm long, and it gives off two thin primary stipes that initially enclose an angle of approximately 80° to 90°, decreasing to about 60°, and eventually becoming nearly parallel or even distally convergent. Most rhabdosomes are lens shaped and may measure as much as 43 mm long and 18 mm wide; commonly they are about 25 to 30 mm long and 10 to 15 mm wide. Each of the primary stipes gives rise to about 7 unbranched secondary stipes that branch off alternately right and left from the plane of the primary stipes. The thecae are of the simple dichograptid type, measuring 0.4 to 0.7 or 0.8 mm wide at the aperture and spaced 10 to 12 per centimeter with very little overlap.

Discussion.—Included in the above description are specimens from the nearby Windy Fork area (southwest corner, McGrath A-2 quadrangle), collected by T.K. Bundtzen and Kristie MacDonald from rocks of the same age (*D.*? *decoratus* Zone) as the Terra Cotta Mountains forms. Those specimens are generally better preserved than the Terra Cotta Mountains specimens and are illustrated in text figures 25*A*, *C*, and *E*. The stipes of the Alaskan form appear to be a bit wider than those of *P. elegans* s.s. (0.4 mm wide). In most other features, the Alaskan form closely resembles *P. elegans*, which is distinguished from other species of *Pterograptus* by the number of its secondary stipes and its lensoid shape.

Occurrences.—Collections 69ACn542, 70ACn72, 70ACn175, and 70ACn301; lower *Diplograptus*? *decoratus* Zone. *P. elegans* occurs in the *Glyptograptus teretiusculus* Zone (=upper *D.*? *decoratus* Zone of Cooper, 1979) (Cobb Bed) in north-west Nelson, New Zealand (Benson and others, 1936; Skwarko, 1962), in the *Didymograptus murchisoni* Zone (Ogygiocaris Series) of the Oslo region, Norway (Berry, 1964), in the *D.*? *decoratus* Zone (Ledbetter Slate) of northeastern Washington (Carter, 1989), and in the *P. elegans* Zone of south-central China (Wang and Jin, 1977).

Pterograptus? sp.

Figure 25*D*

Description.—The single specimen in the collection is poorly preserved and fragmentary, but it has the general appearance and branching habit of *Pterograptus*. The stipes are 0.2 to 0.4 mm wide and bear approximately 5 thecae in 5 mm.

Occurrence.—Collection 69ACn541; lower *Diplograptus*? *decoratus* Zone.

Genus *Temnograptus* Nicholson, 1876
Temnograptus? sp.

Figure 24*B*

Description.—The short funicle measures 2.3 mm in length and gives rise to 4 second-order stipes 5.0 to 6.5 mm long. Each second-order stipe bifurcates into 2 third-order stipes as much as 10 mm long. The stipes are 0.3 to 0.5 mm wide. No fourth-order stipes or thecal outlines were preserved.

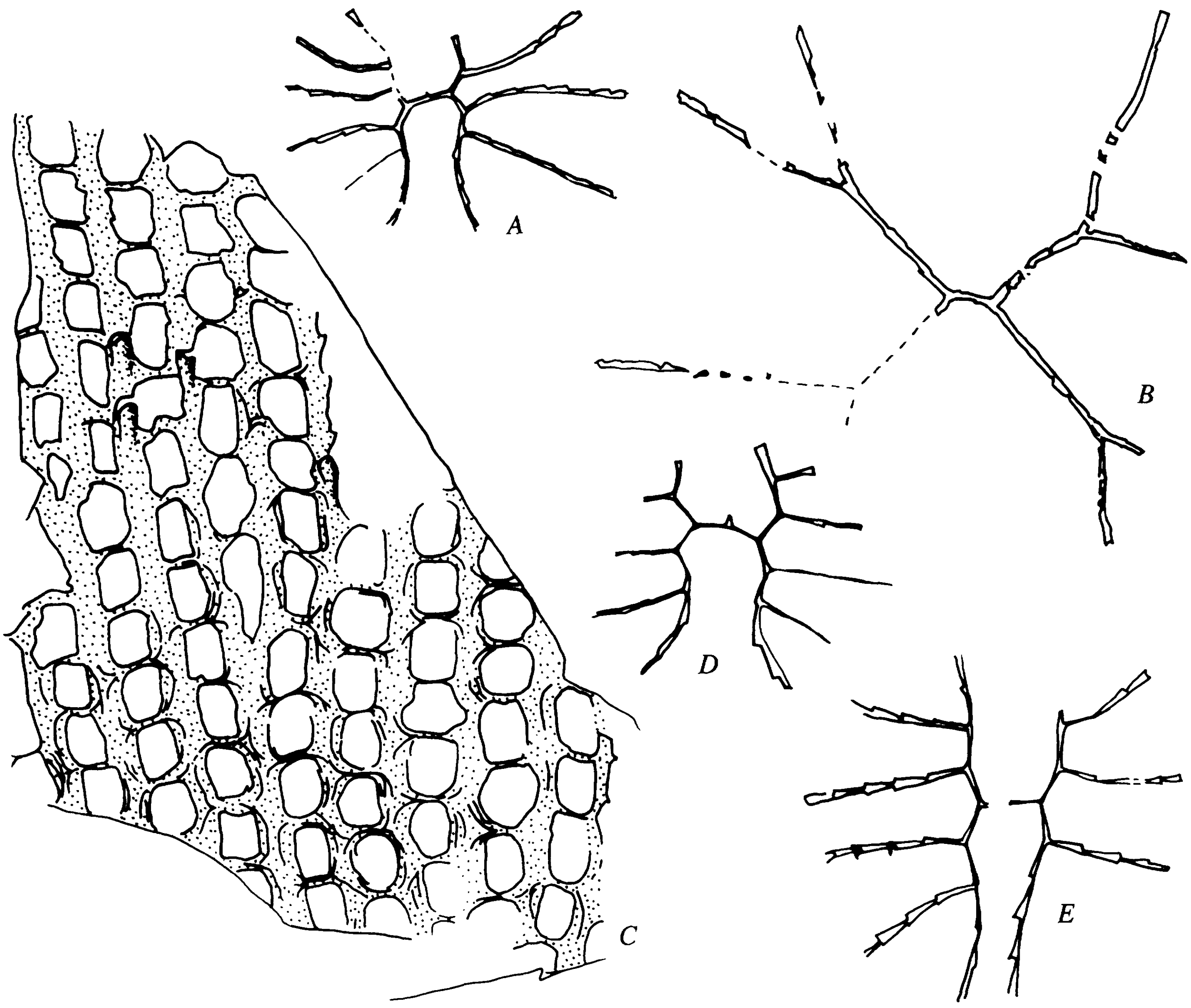


Figure 24. *Brachiograptus*, *Temnograptus*?, and *Araneograptus*?. ***A, D, E, B.*** *etaformis* Harris and Keble, USGS colln. 69ACn391: ***A***, USNM 379193, ×3.5; ***D***, USNM 379269, ×5; ***E***, USNM 379270, ×3.5. ***B***, *Temnograptus*? sp., USNM 379271, showing slight tectonic distortion, USGS colln. 70ACn501, ×3.5. ***C***, *A.*? *murrayi* (Hall), USNM 379272, USGS colln. 69ACn482, ×3.5. Dashed line is extrapolation of missing part of rhabdosome.

Discussion.—The specimen shown in Fig. 24*B* appears to be somewhat tectonically distorted. It resembles *T.* aff. *T. regularis* (Törnquist) as described by Cooper (1979) from New Zealand but has narrower stipes and a shorter funicle.

Occurrence.—Collection 70ACn501; *Adelograptus* Zone.

Genus *Phyllograptus* Hall, 1858, sensu lato
Phyllograptus nobilis Harris and Keble

Figure 26*A*

Phyllograptus nobilis Harris and Keble, 1932, p. 41–42, pl. 6, figs. 3, 4. Berry, 1960, p. 57–58, pl. 14, figs. 6, 7. Berry, 1966, p. 424–426, pl. 44, figs. 6–9.

Diagnosis.—Rhabdosome 12 to 17 mm long and 6.3 to 8.5 mm wide at widest point. Outline is ovoid, sides are nearly parallel in middle third of its length, and length-to-width ratio is 2:1. Thecae number 6 to 7 in proximal 5 mm and 11 to $12^1/_2$ per centimeter distally; they have strongly mucronate apertures.

Discussion.—The Alaskan specimens compare closely with Berry's (1966) description and illustrations of *P. nobilis*. They differ only in being somewhat longer than the Australian specimens (as long as 26 mm). Most are 6 to 7 mm wide (maximum) and about 20 mm long, with 11 to 13 thecae per centimeter. *P. nobilis* resembles *P. ilicifolius* Hall and *P. angustifolius* Hall but can be distinguished from these older species by details of thecae and rhabdosome shape (See Berry, 1966, p.425).

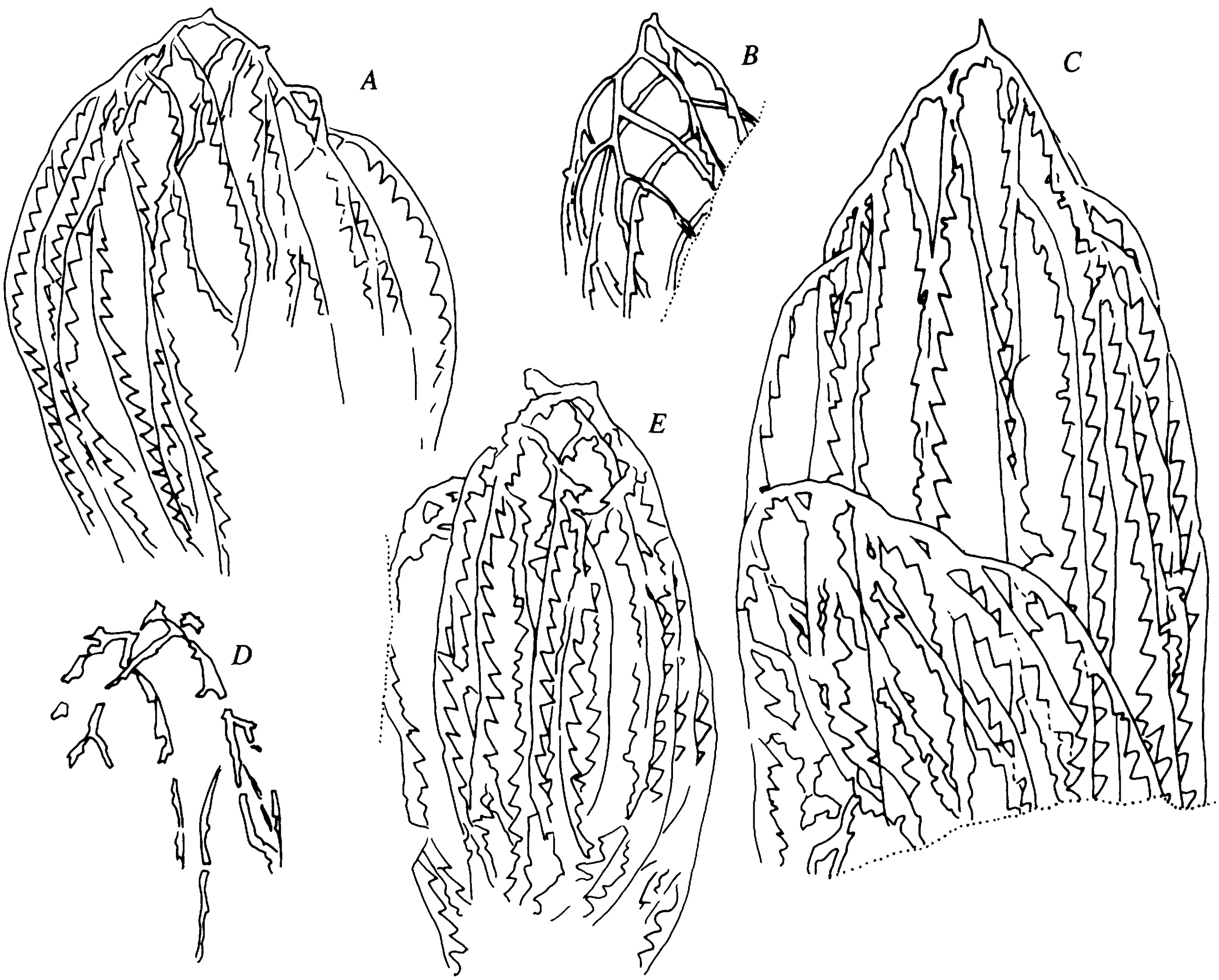


Figure 25. *Pterograptus* and *Pterograptus*?. ***A–C, E***, *P.* cf. *P. elegans* Holm: ***A***, UA-2521, ×3.5, collected by T.K. Bundtzen; ***B***, USNM 379053, USGS colln. 69ACn542, ×5; ***C***, UA-2522, ×5, collected by T.K. Bundtzen; ***E***, UA-2520, ×5, collected by K. MacDonald. ***D***, *P.*? sp., USNM 379054, USGS colln. 69ACn541, ×5. Dotted line indicates edge of rock surface.

Occurrences.—Collections 70ACn71, 70ACn72 and 70ACn301; lower *Diplograptus*? *decoratus* Zone. The Aorangi Mine Formation (*Oncograptus* Zone) in New Zealand (Cooper, 1979). The Zone of *D. decoratus* (Da3) in Australia (Thomas, 1960; Berry, 1966). The Fort Peña Formation (*Glyptograptus* cf. *G. teretiusculus* Zone) in Texas (Berry, 1960).

Phyllograptus n. sp.

Figure 26*B*

Description.—The flattened rhabdosome is 12 mm long and widens rapidly to a maximum of 4.5 mm, which is maintained for most of its length. Thus, the overall outline of the rhabdosome is an elongate oval. The thecae are relatively short, have concave, strongly mucronate apertures, and number 7 in 5 mm proximally, decreasing to 5 in 5 mm distally. The proximal thecae are nearly perpendicular to the rhabdosome axis, and they are more curved than the distal thecae, which become nearly straight at the distal end of the rhabdosome and more inclined to the rhabdosome axis.

Discussion.—The single specimen of this form occurs at the same horizon as *P. nobilis*, from which it differs in size, shape, and thecal spacing. It is wider and has fewer thecae per centimeter than *P. anna longus* Ruedemann and *P. elegans* Ge. Its small size, short thecae, and strongly mucronate thecal apertures distinguish it from all other phyllograptids. However, because only one specimen has been found, it has not been named.

Occurrence.—Collection 70ACn72; lower *Diplograptus*? *decoratus* Zone.

Genus *Didymograptus* McCoy, 1851, sensu lato
Didymograptus cf. *D. cognatus* Harris and Thomas

Figures 26*C–F*

cf. *Didymograptus cognatus* Harris and Thomas, 1935, p. 291–292, fig. 1, nos. 4a–c, fig. 2, nos. 13, 14.

cf. *Acrograptus cognatus* (Harris and Thomas). Tsai, 1974b, p. 85, pl. 7, fig. 16.

Description.—The slender stipes diverge at an angle of 115° to 145° They measure 0.3 mm wide at the first thecal aperture, 0.5 mm wide at the fifth thecal aperture, and 0.7 mm wide at 15 mm from the sicula. The thecae are simple straight tubes with little or no overlap proximally, and they number 8 per centimeter. Some specimens have distal thecae that overlap about one-third and number 8 1/2 per centimeter. The sicula is about 0.6 mm long and relatively broad.

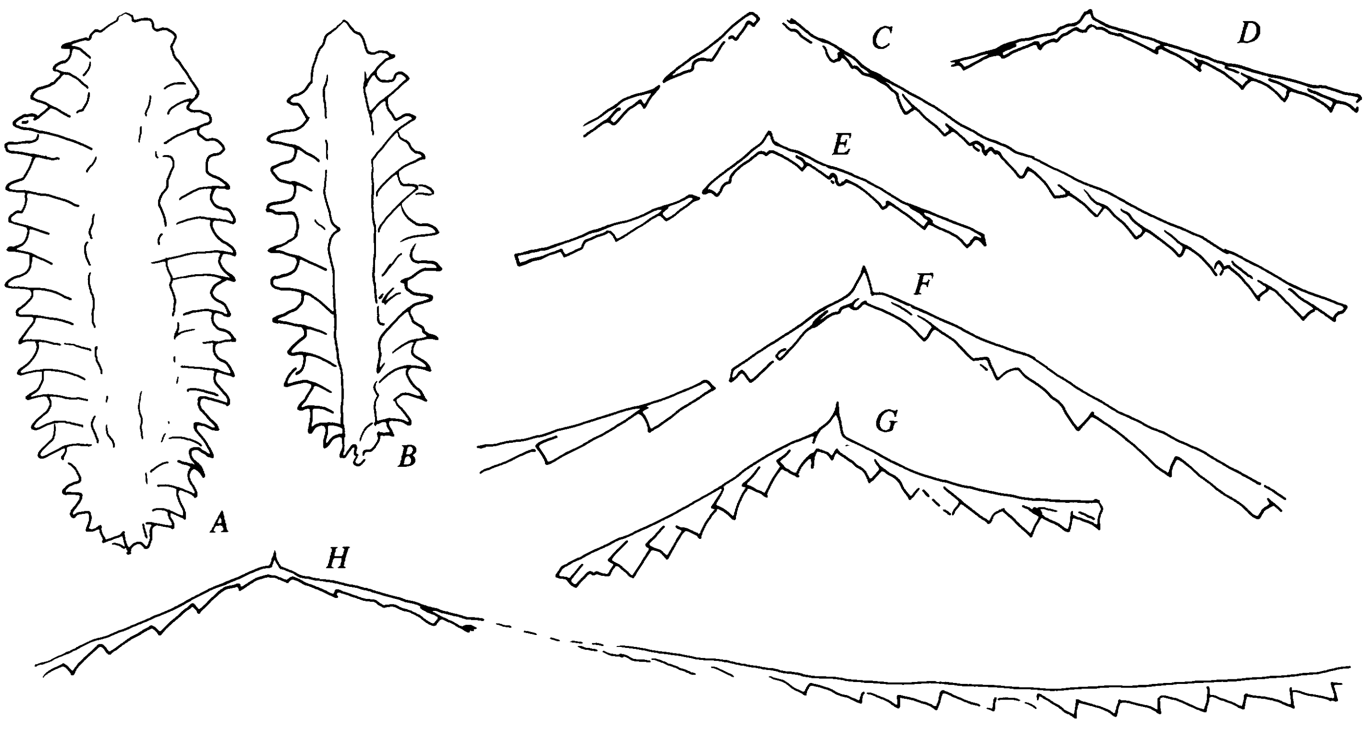


Figure 26. *Phyllograptus* and *Didymograptus*. ***A***, *P. nobilis* Harris and Keble, USNM 379055, USGS colln. 70ACn71, ×5. ***B***, *P.* n. sp., USNM 379056, USGS colln. 70ACn72, ×5. ***C–F***, *D.* cf. *D. cognatus* Harris and Thomas, all from USGS colln. 69ACn541: ***C***, USNM 379057, ×5; ***D***, USNM 379058, ×5; ***E, F***, USNM 379059, ×5 and ×10, respectively. ***G***, *D.* sp. aff. *D. robustus norvegicus* Berry, USNM 379060, USGS colln. 69ACn542, ×5. ***H***, *D.* cf. *D. serra-tulus* (Hall), USNM 379061, USGS colln. 70ACn292, ×5. Dashed line is extrapolation of missing part of rhabdosome.

Discussion.—The Alaskan specimens resemble *D. cognatus* in their slender stipes and their thecal spacing, thecal shape, and low angle of inclination. However, *D. cognatus* is only about 0.4 mm wide and exhibits almost no thecal overlap. In addition, the sicula of *D. cognatus* is described (Harris and Thomas, 1935, p. 292) as being "comparatively long and narrow." The Alaskan specimens also resemble *D. affinis* Nicholson, but *affinis* appears to have greater thecal overlap and more thecae per centimeter (7 to 10).

Occurrences.—Collection 69ACn541; lower *Diplograptus*? *decoratus* Zone. *Didymograptus cognatus* is found in the upper Darriwilian (Da3) beds of Victoria, Australia (Harris and Thomas, 1935; Thomas, 1960) and in the *Expansograptus hirundo* Zone (upper Arenigian) of Kazakhstan (Tsai, 1974b).

Didymograptus sp. aff. *D. robustus norvegicus* Berry

Figure 26*G*

aff. *Didymograptus robustus norvegicus* Berry, 1964, p. 105–107, pl. 7, figs. 1–3.

Description.—The stipes diverge from the sicula at an angle of about 125° initially. They are 0.8 mm wide at the first thecal aperture, increasing to 1.0 mm wide at the fifth thecal aperture, and attaining a maximum width of 1.5 mm (as measured on distal fragments). One stipe is nearly straight and the other curves, in the manner of *D. robustus norvegicus*, so that the angle of divergence increases to 150° distally. The sicula is 1.3 mm long and 0.6 mm wide at its aperture. The thecae number 10 per centimeter initially and $7^1/_2$ to $8^1/_2$ per centimeter on distal fragments. They are straight tubes that increase slightly in width toward their apertures and are about twice as long as they are wide, increasing to four times as long as their width in the distal thecae. Throughout the extent of the stipe, the thecae overlap each other by about one-half their length. They are inclined to the stipe axis at an angle of about 35° proximally, decreasing to 25° distally. The maximum observed length of stipes is 86 mm on a distal fragment.

Discussion.—The Alaskan form is similar to *D. robustus norvegicus* in general size and appearance. It resembles the Norwegian form especially in having one straight and one curved stipe. It differs from that form by having fewer thecae per centimeter, less thecal overlap, and a smaller angle of divergence. In addition, the thecae of the Alaskan form are inclined to the stipe axis at a smaller angle than those of *D. norvegicus*, and they widen less toward the aperture (are nearly parallel sided). The stipes of *D. robustus* Ekstrom are wider (as wide as 2.2 mm) and widen more rapidly than those of *D. r. norvegicus* or the Alaskan form. The general shape of the rhabdosome with one nearly straight stipe and one stipe distinctly curved in its proximal portion distinguishes these forms from all other didymograptids. The Alaskan form may be a new subspecies of *D. robustus*, but the material consists of one immature(?) specimen (fig. 26*G*) and nine distal fragments, which is insufficient to establish a new taxon.

Occurrences.—Collections 69ACn542 and 69ACn543A; *Diplograptus*? *decoratus* Zone.

Didymograptus cf. *D. serratulus* (Hall)

Figure 26*H*

cf. *Graptolithus serratulus* Hall, 1847, p. 247, pl. 74, figs. 5*a*, *b*.
cf. *Didymograptus serratulus* (Hall). Ruedemann, 1908, p. 251–253, text figs. 156–159, pl. 14, fig. 4. Ruedemann, 1947, p. 346, pl. 54, figs. 49–51.

Description.—The stipes diverge from the sicula at an angle of 140° and gradually widen from an initial width of 0.3 mm to a maximum width of 0.8 mm at a distance of 3 cm from the sicula. The thecae number 8 to 9 per centimeter and exhibit little or no overlap proximally; distally, they overlap less than one-third of their length. They are inclined at a low angle (10° to 20°) to the stipe axis. The sicula is relatively small, only 0.7 mm long.

Discussion.—The single Alaskan specimen is slightly narrower and has a shorter sicula than *D. serratulus* sensu stricto. It also resembles *D. nicholsoni* Lapworth in general appearance and width of stipes. It differs from that species in having a greater angle of divergence of the stipes, fewer thecae per centimeter, a shorter sicula, and gently curved stipes.

Occurrences.—Collection 70ACn292; *Climacograptus bicornis* Zone. *D. serratulus* occurs in the *Diplograptus*? *decoratus* Zone (Ledbetter Slate) in northeastern Washington (Carter, 1989) and in the *N. gracilis* Zone (Normanskill Shale) in New York (Ruedemann, 1908; 1947).

Family ISOGRAPTIDAE Harris, 1933, sensu Cooper and Ni, 1986

Genus *Isograptus* Moberg, 1892

Isograptus caduceus? *nanus* (Ruedemann)

Figures 27*D–G*, *I*, *K*

Didymograptus caduceus nanus Ruedemann, 1904, p. 698, text fig. 90, pl. 15, figs. 8, 9.
Isograptus caduceus? *nanus* (Ruedemann). Cooper, 1971, p. 906, text-figs. 3g, h.
Isograptus caduceus nanus (Ruedemann). Lenz and Jackson, 1986, figs. 8C, 9E.

Revised diagnosis.—Rhabdosome small, not more than 5 mm long and 3.5 to 4.2 mm wide at its widest point. Sicula 3.0 mm long and 0.6 to 0.7 mm wide at its aperture. Stipes truncated, extending only one or two thecae above the apex of the sicula.

Description.—The small rhabdosomes of the Alaskan specimens consist of a sicula 3.0 mm long (one specimen is

3.5 mm long) and about 12 thecae, 4 or 5 of which are pendent. The indentation between the sicula and first theca is 0.4 to 0.5 mm long and the supradorsal portion of the sicula is 0.4 to 0.7 mm (mostly 0.5 mm) long. The stipes are very short, seldom extending above the level of the apex of the sicula. The thecae bear prominent ventral apertural denticles.

Discussion.—As Cooper (1971) has noted, this subspecies is difficult to distinguish from immature specimens of *I. caduceus caduceus* (Salter) and may actually be related to *I. forcipiformis* (Ruedemann). The Alaskan specimens do not occur with any other isograptids, and there is thus no indication that they are simply immature specimens of some other species.

Occurrences.—Collection 70ACn81; *Paraglossograptus tentaculatus* Zone. *Glyptograptus dentatus* Zone (=*Hallograptus etheridgei* Zone of Berry, 1960), Deepkill Shale, New York (Ruedemann, 1947; Cooper, 1971). *P. tentaculatus* Zone in the Canadian Cordillera (Lenz and Jackson, 1986).

Isograptus cf. *I. forcipiformis* (Ruedemann)

Figure 27*A*

cf. *Didymograptus forcipiformis* Ruedemann, 1904, p. 699–700, text fig. 91, pl. 15, figs. 10–13.

cf. *Isograptus forcipiformis* (Ruedemann). Cooper, 1971, p. 906, text-figs. 3a–e.

Description.—The rhabdosome is approximately V-shaped; the stipes are widest at their bases and taper distally to a width of about 1.5 mm. The sicula and first theca are about 6 mm long, with an 0.8-mm-deep ventral indentation between them; they extend above the dorsal margin of the stipes (supradorsal height) for about 2 mm. The rhabdosome appears to have 6 or 7 pendent thecae and the stipes bear about 5 thecae in 5 mm. The thecae have deeply concave apertural margins that extend into prominent ventral denticles.

Discussion.—The single Alaskan specimen resembles *I. forcipiformis* in the shape of the rhabdosome, particularly in the relatively great initial width and subsequent tapering of the stipes. In *I. forcipiformis*, however, the stipes are more nearly parallel, its sicula is much shorter (3.8 to 4.5 mm long), the supradorsal length of its sicula is much less, and its ventral indentation is smaller than in the Alaskan form. From *I. caduceus caduceus* (Salter), which it resembles in shape, tapering stipes, ventral indentation, and number of pendent thecae, the Alaskan form is distinguished by its much longer sicula and deeper proximal portion.

Occurrences.—Collection 70ACn743; *Oncograptus* Zone. *I. forcipiformis* occurs in the *Glyptograptus dentatus* Zone at Mt. Merino, New York (Ruedemann, 1904), in beds of Darriwilian age in Victoria, Australia (VandenBerg, 1981), and in the Glenogle Formation (*Paraglossograptus etheridgei* Zone) of British Columbia (Larson and Jackson, 1966).

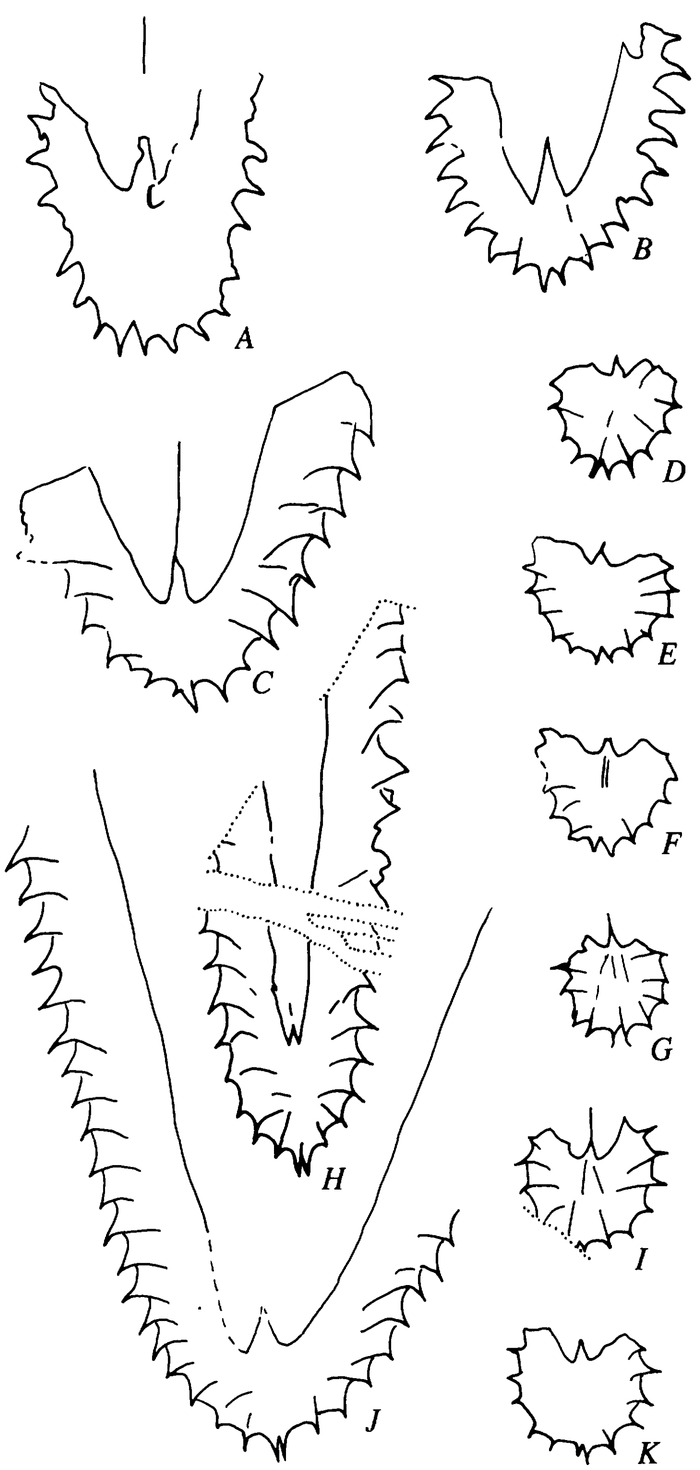


Figure 27. *Isograptus* (all ×5). ***A***, *I.* cf. *I. forcipiformis* (Ruedemann), USNM 379068, USGS colln. 70ACn743. ***B***, *I.* sp. A, USNM 379072, USGS colln. 70ACn743. ***C***, ***J***, *I.* cf. *I. victoriae divergens* Harris: ***C***, USNM 379070, USGS colln. 70ACn132; ***J***, USNM 379071, USGS colln. 70ACn82. ***D–G***, ***I***, ***K***, *I. caduceus*? *nanus* (Ruedemann), all from USGS colln. 70ACn81: ***D***, USNM 379062; ***E***, USNM 379063; **F**, USNM 379064; **G**, USNM 379065; **I**, USNM 379066; ***K***, USNM 379067. ***H***, *I.* sp. C, USNM 379069, USGS colln. 70ACn132.

Isograptus cf. *I. victoriae divergens* Harris

Figures 27*C*, *J*

cf. *Isograptus caduceus* var. *divergens* Harris, 1933, p. 91, text figs. 14–18.

cf. *Isograptus victoriae divergens* Harris. Cooper, 1973, p. 69–70, text-figs. 13b–d. Carter and Tailleur, 1984, p. 49, fig. 6E.

Description.—The rhabdosome is large and V-shaped. The sicula is 4.2 mm long and the supradorsal portion of the sicula and $th1^1$ is 1.5 mm long. The stipes are 2.2 to 2.3 mm wide proximally and widen gradually to a maximum of 2.7 mm distally. They are generally straight and diverge at 320° to 330°. The thecae have prominent apertural denticles and are spaced 10 to 11 per centimeter.

Discussion.—The Alaskan forms closely resemble *I. victoriae divergens* but differ from it by having narrower stipes (compared to 4 to 5 mm wide in *I. v. divergens*) and more thecae per centimeter (9 per centimeter in *I. v. divergens*). Cooper (1973) included *I. furcula* Ruedemann as a synonym of *I. v. divergens*, and, according to Ruedemann (1947, p. 353), *I. furcula* has stipes measuring 3 mm wide, which is close to the dimension of the Alaskan specimens.

Occurrences.—Collections 70ACn82 and 70ACn132; *Oncograptus* Zone. *I. victoriae divergens* occurs in the Baird Mountains of the western Brooks Range, Alaska (Carter and Tailleur, 1984), the Aorangi Mine Formation (*Oncograptus* Zone) in New Zealand (Cooper, 1979), the Zones of *O. upsilon* through *Diplograptus*? *decoratus* in Victoria, Australia (VandenBerg, 1981), the Glenogle Formation in British Columbia (Ruedemann, 1947), and the Metaline Formation (*Paraglossograptus tentaculatus* Zone) in northeastern Washington (Carter, 1989).

Isograptus sp. A

Figure 27*B*

Description.—The rhabdosome is small, with a relatively large sicula and $th1^1$. The sicula is 4.0 mm long, and 1.75 mm of its length extends above the dorsal margin of the stipes. The stipes are 2 mm wide and maintain that width throughout their length. The thecae number about $6^1/_2$ in 5 mm; their apertures are drawn out into very pronounced denticles, and the apertural margins are convex, in contrast to the usual concave margins of most isograptids.

Discussion.—The single specimen of this form looks similar to *Pseudisograptus manubriatus* (T.S. Hall), but the supradorsal portion of the sicula and first theca is not as wide as in that species and it does not have the shoulders of a true manubrium. The Alaskan form also resembles *I. primulus* Harris and *I. victoriae lunatus* Harris, but it has a larger sicula with a longer supradorsal portion and fewer pendent thecae than *I. primulus*. It lacks the conspicuous wide indentation between the sicula and $th1^1$ that is characteristic of *I. v. lunatus*, and its sicula is longer.

Occurrence.—Collection 70ACn743; *Oncograptus* Zone

Isograptus sp. C

Figure 27*H*

Description.—The stipes diverge at a very great angle so that their dorsal margins are nearly parallel above the sicula. They are 1.8 mm wide at the level of the apex of the sicula and about 2 mm wide distally, bearing 9 to 10 thecae per centimeter. The sicula is 4.0 mm long, with only 0.4 mm of its length free above the dorsal margin of the stipes. The small ventral indentation between the sicula and $th1^1$ is about 0.6 mm long, and there are approximately 5 pendent thecae.

Discussion.—This graptolite resembles *I. forcipiformis latus* Ruedemann in its nearly parallel, untapering stipes. However, *I. f. latus* has wider stipes (2.6 to 3.0 mm) and fewer thecae per cm (8 to $8^1/_2$, according to Cooper, 1970). The Alaskan specimen also looks like *I. caduceus caduceus* (Salter), but it differs somewhat in dimensions, thecal spacing, and angle of stipe divergence. Because only one specimen of this form was found, and it doesn't conform more closely to the diagnosis of either *I. c. caduceus* or *I. f. latus*, it has been left in open nomenclature.

Occurrence.—Collection 70ACn132; *Oncograptus* Zone.

Family GLOSSOGRAPTIDAE Lapworth, 1873, emend. Cooper and Ni, 1986
Subfamily GLOSSOGRAPTINAE Lapworth, 1873
Genus *Apiograptus* Cooper and McLaurin, 1974
?*Apiograptus* ?*crudus* (Harris and Thomas)

Figure 28*D*

?*Glossograptus*? *crudus* Harris and Thomas, 1935, p. 303–304, fig. 1, no. 13; fig. 2, nos. 15–17.

?*Apiograptus crudus* (Harris and Thomas). Cooper and McLaurin, 1974, p. 81–84, text-figs. 2a–h. Cooper, 1979, p. 80, text fig. 62, pl. 15, fig i.

Description.—The single Alaskan specimen is poorly preserved. It measures 13 mm long and 3.0 to 3.5 mm wide. The thecae number 12 per centimeter, and their apertural margins appear slightly convex and are extended ventrally into prominently projecting processes.

Discussion.—Because the details of the proximal end of this specimen are obscured by breakage and poor preservation, it can only be questionably referred to the species *A. crudus*. But it closely resembles *A. crudus* in size and thecal characters. It also resembles some wider-than-usual specimens of *Cryptograptus schaeferi* Lapworth from collection 70ACn72 (figs. 29*A–F*) but is considerably wider and occurs two zones below them in the Terra Cotta Mountains graptolite succession.

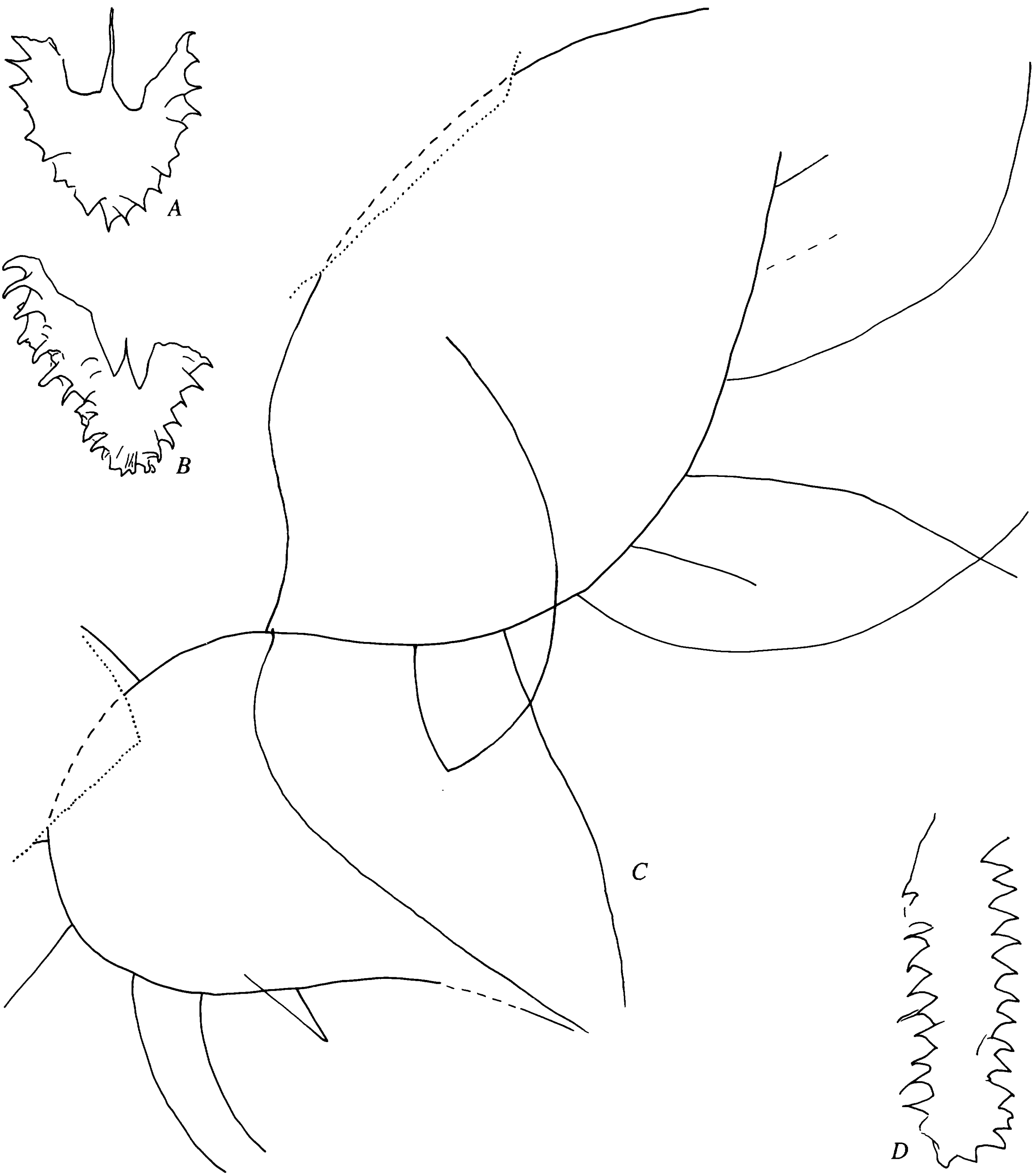


Figure 28. *Pseudisograptus*, *Kalpinograptus*, *Pleurograptus*, and ?*Apiograptus*. ***A***, *Pseudisograptus* cf. *P. jiangxiensis* (Yu and Fang), USNM 379073, USGS colln. 70ACn743, ×5. ***B***, *K.* cf. *K. ovatus* (T.S. Hall), USNM 379074, USGS colln. 69ACn547, ×5. ***C***, *Pleurograptus collatus* n. sp., USNM 379079, USGS colln. 70ACn292; tracing of specimen (natural size), showing arrangement of branches but omitting details of thecae and true width of stipes (see figs. 30*A*, *E* for details). ***D***, ?*A*. ?*crudus* (Harris and Thomas), USNM 379075, USGS colln. 70ACn743, ×5. Dashed lines are extrapolations of missing parts of rhabdosomes. Dotted line indicates edge of rock surface.

Occurrences.—Collection 70ACn743; *Oncograptus* Zone. *A. crudus* occurs in rocks of Yapeenian (Ya2) age in Victoria, Australia, and in the Zone of *Oncograptus* (Aorangi Mine Formation) in New Zealand (Cooper, 1979). Questionably reported from the *Oncograptus* Zone (Descon Formation) in southeastern Alaska (Carter, unpub. data, 1983), from the Baird Mountains of the western Brooks Range, Alaska (Carter and Tailleur, 1984) and from the Ledbetter Slate in Washington (Carter, 1989).

Genus *Cryptograptus* Lapworth, 1880
Cryptograptus schaeferi Lapworth

Figures 29*A–H*

Cryptograptus tricornis var. *schaeferi* Lapworth, 1880, pl. 5, figs. 28A, B.
Cryptograptus tricornis var. *schäferi* Lapworth. Elles and Wood, 1901–1918, p. 299, pl. 32, figs. 13a–c.
Cryptograptus schäferi (Lapworth). Harris and Thomas, 1935, p. 304, fig. 3, nos. 11, 12. Skwarko, 1962, p. 225, text-fig. 4, figs. 10a, b. ?Berry, 1960, p. 69, pl. 12, figs. 7, 8. Lenz and Chen, 1985, pl. 3, figs. 2, 3.
Not *Cryptograptus tricornis* (Carruthers) var. *schäferi* Lapworth. Ruedemann, 1947, p. 447, pl. 76, fig. 48.
Cryptograptus schäferi Lapworth. Ross and Berry, 1963, p. 96–97, pl. 5, figs. 28, 29.
Cryptograptus tricornis var. *schaeferi* Lapworth. Berry, 1964, p. 117–118, pl. 11, figs. 7–8.
Cryptograptus tricornis schaeferi Lapworth. Skevington, 1970, p. 418–422, figs. 6a–h, 7a–d.
Cryptograptus schaferi Lapworth. Cooper, 1979, p. 80, pls. 15d, jB; fig. 63.

Diagnosis.—Rhabdosome as much as 4 cm long (usually 2 to 3 cm long). Maximum width in scalariform view 1.2 to 2.2 mm (usually 1.4 to 1.6 mm wide), attained within the first 7 to 8 mm of rhabdosome length. Thecae number 7 to 8 in first 5 mm and 10 to 11 per centimeter distally. In lateral view, free ventral edges of thecae are drawn out into spine-like projections.

Discussion.—*C. schaeferi* may be distinguished from *C. tricornis* (Carruthers) by the lateral profile of its rhabdosome (the supragenicular walls of *C. tricornis* are aligned nearly parallel to the rhabdosome axis rather than being drawn out into the spine-like projections of *C. schaeferi*) and by the closer spacing of its proximal thecae (*C. tricornis* has 10 to 12 thecae per cm).

The Alaskan specimens agree well with the above description, although none exceed about 15 mm in length. In addition to the typical forms, which have a maximum width in lateral view of 2.0 mm, some unusually wide forms occur in collection 70ACn72 (figs. 29*A–F*). These measure as much as 3 mm wide in lateral view (including thecal projections) and are not merely tectonically distorted. Measurement of Skevington's (1970, figs. 6g, 7b, 7d) illustrations (and conversion to actual dimensions) yields maximum widths of 2.5 to 2.6 mm for specimens of *C. schaeferi* in lateral view. Most of the Alaskan wide forms fall within this limit; however, they are conspicuously wider than the typical specimens of *C. schaeferi* occurring with them in collections 70ACn72 and in the other Terra Cotta Mountains collections.

Occurrences.—Collections 69ACn541, 69ACn542, 69ACn545, 70ACn71, 70ACn72, and 70ACn175; *Diplograptus*? *decoratus* Zone. *C. schaeferi* is a well known and

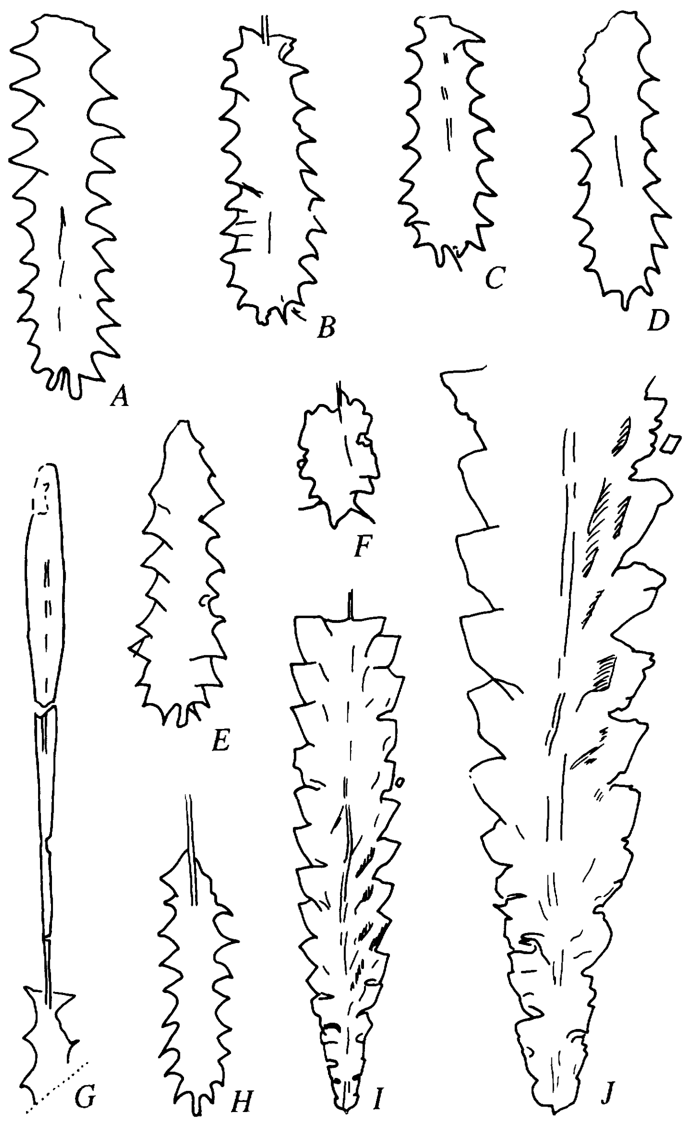


Figure 29. *Cryptograptus* and *Diplograptus*. ***A–H***, *C. schaeferi* Lapworth, all from USGS colln. 70ACn72, all ×5: ***A***, USNM 379100, wide form; ***B***, USNM 379101, wide form; ***C***, USNM 379102, wide form; ***D***, USNM 379103, wide form; ***E***, USNM 379104, wide form; ***F***, USNM 379105, wide form showing proximal lateral spines; ***G***, USNM 379106, typical form; ***H***, USNM 379107, typical form. ***I, J***, *D. mucroterminatus* Churkin and Carter, USNM 379108, USGS colln. 69ACn363, ×5 and ×10, respectively.

widespread species, occurring in northwestern Canada (Lenz and Chen, 1985), Australia (Harris and Thomas, 1935), New Zealand (Skwarko, 1962; Cooper, 1979), Nevada (Ross and Berry, 1963), Texas (Berry, 1960), the British Isles (Elles and Wood, 1901–1918; Skevington, 1970), Norway (Berry, 1964), and the former USSR (Tsai, 1974).

Genus *Kalpinograptus* Jiao, 1977
***Kalpinograptus* cf. *K. ovatus* (T.S. Hall)**

Figure 28*B*

cf. *Didymograptus ovatus* T.S. Hall, 1900, p. 33, fig. 1
cf. *Kalpinograptus ovatus* (T.S. Hall). Carter, 1989, p. B7, figs. 6*D*, *E*

Description.—The single specimen is not well preserved. The sicula is approximately 4 mm long. The rhabdosome is V-shaped, and the stipes are 1.5 to 2.0 mm wide, bearing 12 thecae per centimeter. The thecal apertures are drawn out into prominent denticles.

Discussion.—The Alaskan specimen resembles *K. ovatus* in the shape of its rhabdosome, its strongly denticulate thecal apertures, and its general dimensions.

Occurrences.—Collection 69ACn547; *Dicellograptus* Zone. *K. ovatus* occurs in the Ledbetter Slate (*Diplograptus*? *decoratus* Zone) (Carter, 1989) and the upper Darriwilian in Australia (Beavis and Beavis, 1974; VandenBerg, 1981).

Subfamily PSEUDISOGRAPTINAE Cooper and Ni, 1986
Genus *Pseudisograptus* Beavis, 1972
***Pseudisograptus* cf. *P. jiangxiensis* (Yu and Fang)**

Figure 28*A*

cf. *Isograptus dumosus* Harris, Form C. Cooper, 1973, p. 78–82, text-figs. 18a–d (not text figs. 18e–p).
cf. *Pseudisograptus dumosus* (Harris), Form C. Cooper, 1979, p. 77–78, figs. 58a–b.
cf. *Arienigraptus jiangxiensis* Yu and Fang, 1981, p. 29–30, pl. 1, figs. 1, 2, text fig. 3.
cf. *Pseudisograptus jiangxiensis* (Yu and Fang). Cooper and Ni, 1986, p. 355–357, pl. 25, figs. 1, 6, text-figs. 26L–R.

Discussion.—The Alaskan specimen matches *P. jiangxiensis* in the length of its sicula (6.0 mm) and the depth of its proximal region. However, its stipes are more robust, measuring 2.0 mm wide and bearing about 4 thecae.

Occurrences.—Collection 70ACn743; *Oncograptus* Zone. *P. jiangxiensis* is restricted to the lower *Oncograptus* Zone in New Zealand and the equivalent Ya1 in Australia (Cooper and Ni, 1986). In China, it is found in the *Glyptograptus austrodentatus* and *Cardiograptus amplus* Zones (Yu and Fang, 1981).

Family NEMAGRAPTIDAE Lapworth, 1873
Genus *Leptograptus* Lapworth, 1873
***Leptograptus* cf. *L. validus incisus* Elles and Wood**

Figure 30*B–D*

cf. *Leptograptus validus* var. *incisus* Elles and Wood, 1901–1918, p. 114–115, text figs. 69*a*, *b*, pl. 16, figs. 2a, b.

Description.—The sicula is prominent, measuring 1.8 to 2.5 mm long (most are 2 mm long). It gives rise to a pair of gently reclined stipes that are generally straight after their initial flexure. The stipes are 0.3 to 0.4 mm wide at the aperture of the first theca, and they increase gradually to a maximum width of 0.5 to 0.7 mm. The thecae are of the leptograptid type, numbering 8 1/2 to 10 per centimeter and overlapping approximately one-third their length or less.

Discussion.—The Alaskan specimens agree well with *L. validus incisus* in dimensions and general shape, but some of them exhibit a greater initial flexure of their stipes than does *L. v. incisus.* Both forms are distinguished by the narrowness of the stipes, the length of the sicula, and the generally straight habit (after initial flexure) of the stipes.

Occurrences.—Collections 70ACn62, 69ACn557, 69ACn558, and 69ACn559A; *Climacograptus bicornis* Zone. *L. validus incisus* occurs in the Glenkiln Shales (*Nemagraptus gracilis* Zone) of southern Scotland (Elles and Wood, 1901–1918). It is also tentatively reported from the Woods Hollow Shale (*N. gracilis* and *C. bicornis* Zones) of the Marathon region, Texas (Berry, 1960).

Genus *Pleurograptus* Nicholson, 1867
***Pleurograptus collatus* n. sp.**

Figures 28*C*, 30*A*, *E*

Diagnosis.—Rhabdosome consists of two main stipes, each 14 to 17 cm long and bearing at least 8 secondary branches. Stipes and branches are 0.25 to 0.5 mm wide and bear 8 thecae per centimeter.

Description.—The rhabdosome consists of 2 gracefully curved main stipes that each give rise to at least 8 gently curved, unbranched secondary branches. The main stipes diverge from the sicula at 180° and measure 14 to 17 cm long. The first secondary branch on each main stipe arises at, or very close to the sicula (about 1 mm away). The second secondary branch is given off 23 to 24 mm away from the first branch, and from that point on, the secondary branches arise quite regularly, 12 to 17 mm apart. The secondary branches are as much as 15 cm long, and are all restricted to the convex side of their curved main stipes, much in the manner of *Nemagraptus gracilis* (Hall). The main stipes are 0.25 mm wide near the sicula and as much as 0.5 mm wide distally, although they and the secondary branches average 0.3 to 0.4 mm in width. The thecae are of the leptograptid type and number 8 per centimeter. The sicula is about 1 mm long.

Discussion.—*P. collatus* has narrower stipes than *P. linearis* (Carruthers) and *P. linearis simplex* Elles and Wood. Its secondary branches are unbranched and are given off fairly regularly, in contrast to those of *P. linearis linearis*. *P. collatus* resembles *P. linearis simplex* in the regular spacing of its secondary branches, but it has at least 8 branches per main stipe, while *P. l. simplex* usually has only 3.

Occurrences.—Collection 70ACn292, a mixed float collection mostly containing species of the *Climacograptus bicornis* Zone. The single specimen of *P. collatus* occurs on the same piece of rock with three large climacograptids (*C. tubuliferus*?) and a large *Orthograptus* sp.

Family DICRANOGRAPTIDAE Lapworth, 1873
Genus *Dicranograptus* Hall, 1865
Dicranograptus contortus Ruedemann

Figure 31*A*

Dicranograptus contortus Ruedemann, 1908, p. 337–338, pl. 23, fig. 9, text figs. 275–278. Ross and Berry, 1963, p. 109, pl. 7, figs. 9, 14. Carter and Churkin, 1977, p. 17, pl. 2, fig. 6; pl. 7, fig. 4. Finney, 1986, fig. 12C.

Diagnosis.—Rhabdosome small, consisting of short biserial portion that is 3 mm long and 0.8 mm wide, and 2 relatively thick uniserial, uniformly wide (0.7 mm) branches that are intricately contorted. Biserial portion has 5 thecae on either side, uniserial branches have 18 to 20 thecae per centimeter. Proximal end has long virgella and conspicuous lateral spines.

Description.—The Alaskan specimens have biserial portions 1.8 to 3.0 mm long (most are 2 mm long) and 0.7 to 1.0 mm wide. Their uniserial branches are 0.5 to 0.6 mm wide and curved so that they diverge widely; the axial angle approaches 150° or 160° after an initial divergence of about 70°. The branches are generally short, about 2 or 3 mm long, although some reach a length of over 5 mm. Near their distal ends they usually bend sharply toward the rhabdosome axis. Details of the thecae are not visible in the Alaskan specimens, but the proximal thecae on the biserial portion commonly bear genicular(?) spines.

Discussion.—*D. contortus* resembles *D. hians kirki* Ruedemann in its short biserial portion and its curved uniserial branches, but *contortus* has a much wider axial angle and much shorter, more contorted branches.

Occurrences.—Collections 69ACn351, 69ACn412, 69ACn558, 69ACn562, and 70ACn182; *Climacograptus bicornis* Zone. *Nemagraptus* and *C. bicornis* Zones (Phi Kappa Formation) at Trail Creek, Idaho (Carter and Churkin, 1977). Normanskill Shale in New York (Ruedemann, 1947). *N. gracilis* Zone (Woods Hollow Shale) in the Marathon region, Texas (Berry, 1960). *C. bicornis* Zone (Descon Formation) in southeastern Alaska (Carter, unpub. data, 1983).

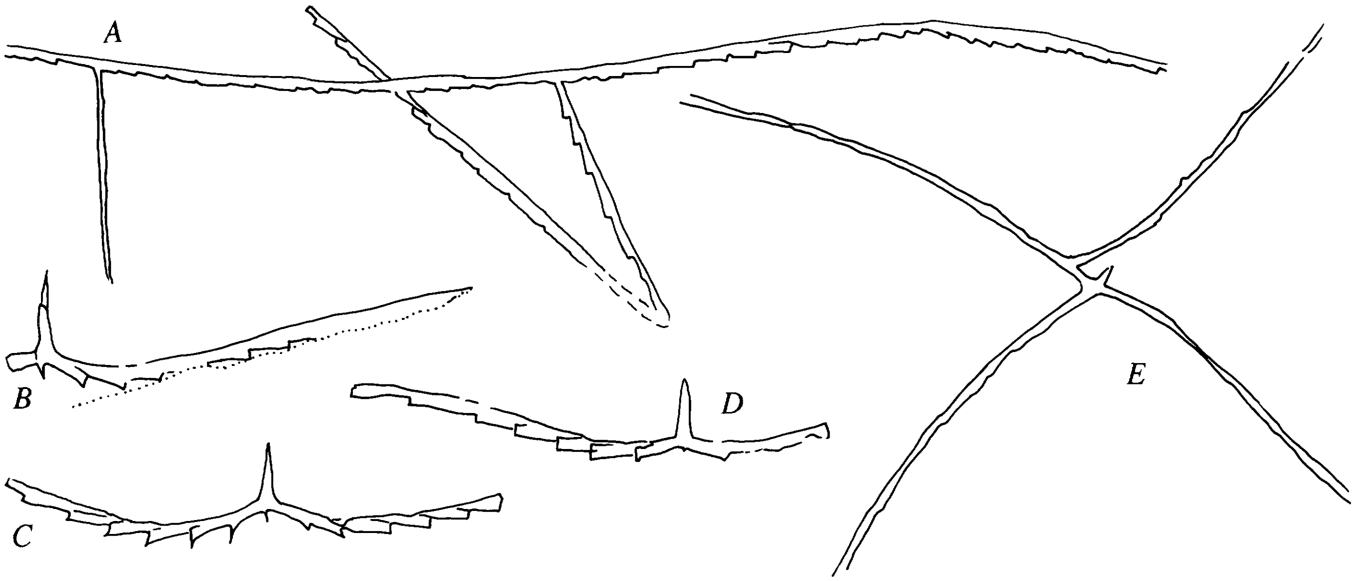


Figure 30. *Pleurograptus* and *Leptograptus*. ***A***, ***E***, *P. collatus* n. sp., USNM 379079, USGS colln. 70ACn292, ×3.5; detail of large rhabdosome depicted in figure 28*C*. ***B–D***, *L.* cf. *L. validus incisus* Elles and Wood, all ×5: ***B***, USNM 379076, USGS colln. 69ACn557; ***C***, USNM 379077, USGS colln. 69ACn558; ***D***, USNM 379078, USGS colln. 69ACn557. Dashed line is extrapolation of missing part of rhabdosome. Dotted line indicates edge of rock surface.

Dicranograptus aff. *D. furcatus* (Hall)

Figures 31*B*, *C*

aff. *Graptolithus furcatus* Hall, 1847, p. 273, pl. 74, figs. 4*a-h*.
aff. *Dicranograptus furcatus* (Hall). Ruedemann, 1908, p. 334–336, text figs. 268–272, pl. 23, fig. 7. Ruedemann, 1947, p. 389–390, pl. 65, figs. 37–42.

Description.—The biserial portion of the single Alaskan specimen is only. 1.5 mm long and 0.5 to 0.8 mm wide, with 3(?) pairs of thecae. The uniserial branches are 0.7 to 0.8 mm wide, with approximately 8 to 10 thecae in 5 mm. The ventral walls of the thecae are strongly curved and furnished with mesial spines. The branches cross each other about 2.5 mm above their origin and again about 3 mm above the first crossing.

Discussion.—This form resembles *Dicranograptus ziczac* Lapworth and *D. furcatus* in the crossing habit of its stipes, but it is much smaller overall than *D. ziczac*. It has a shorter biserial portion, narrower uniserial branches with more thecae per centimeter, and a much closer spacing of stipe crossings than *D. furcatus* and *D. furcatus exilis* Ruedemann. It resembles *D. brevicaulis* Elles and Wood in its short biserial portion but lacks that species' straight uniserial stipes.

Occurrence.—Collection 69ACn549A; *Dicellograptus* Zone.

Genus *Dicellograptus* Hopkinson, 1871
Dicellograptus alector Carter

Figure 31*G*

Dicellograptus alector Carter, 1972, p. 46–47, text-figs. 2A, G; pl. 1, figs. 9, 11, 12, 15. Carter and Churkin, 1977, p. 18, pl. 3, figs. 8, 12, 13, 17.

Discussion.—The specimen illustrated (fig. 31*G*) has stipes 0.5 to 1.0 mm wide and 9 to 10 thecae per centimeter, which is within the parameters of the original description of *D. alector*. It has an unusually long lateral spine that measures 3.5 mm in length. *D. alector* may be synonymous with *D. gravis* Keble and Harris, an Australian form whose type specimens are not good (damaged or missing axils) (A.H.M. VandenBerg, written commun., 1983). Therefore the name *D. alector* has been retained until such time as *D. gravis* is redescribed.

Occurrences.—Collections 69ACn574 and 70ACn142; *Climacograptus tubuliferus* Zone. *C. tubuliferus* and *P. linearis* Zones (Phi Kappa Formation) at Trail Creek, Idaho (Carter and Churkin, 1977), and in Nevada (Carter, 1972). Descon Formation, southeastern Alaska (Carter, unpub. data, 1983) *D. gravis* occurs in the *D. gravis* Zone (upper Eastonian) in Australia (VandenBerg, 1981).

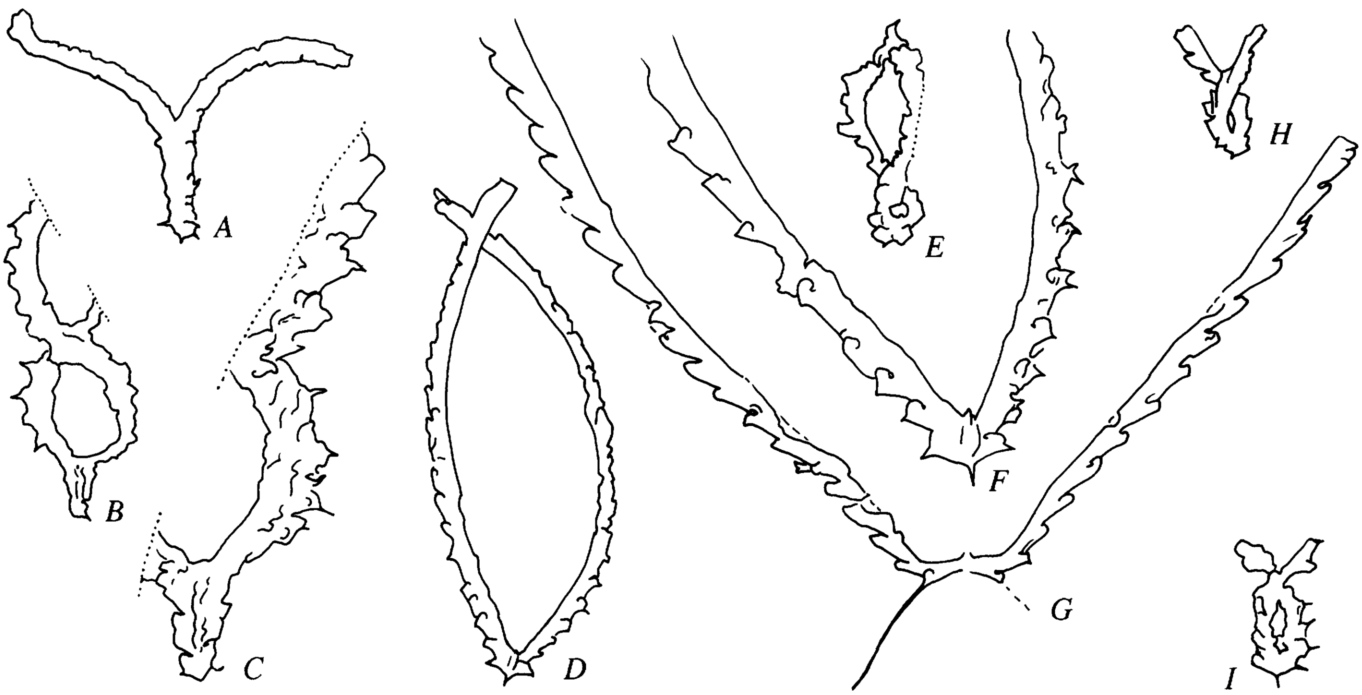


Figure 31. *Dicranograptus* and *Dicellograptus*. ***A***, *Dicranograptus contortus* Ruedemann, USNM 379080, USGS colln. 69ACn558, ×5. ***B***, ***C***, ***D***. aff. *D. furcatus* (Hall), USGS colln. 69ACn549A: ***B***, USNM 379081, ×5; ***C***, USNM 379081 (counterpart), ×10. ***D***, ***F***, *Dicellograptus* cf. *D. caduceus* Lapworth, USNM 379086, USGS colln. 69ACn547, ×5 and ×10, respectively. ***E***, ***H***, ***I***, *D. bispiralis* (Ruedemann), all from USGS colln. 69ACn549A, all ×5: ***E***, USNM 379083; ***H***, USNM 379084; ***I***, USNM 379085. ***G***, *D. alector* Carter, USNM 379082, USGS colln. 70ACn142, ×5. Dotted line indicates edge of rock surface.

Dicellograptus bispiralis (Ruedemann)

Figures 31*E, H, I*

Dicranograptus furcatus var. *bispiralis* Ruedemann, 1947, p. 390, pl. 65, figs. 46, 47.
Dicellograptus bispiralis (Ruedemann). Wang and Jin, 1977, p. 310, pl. 97, fig. 1. ?Lenz and Chen, 1985, pl. 1, figs. 28–30.

Revised diagnosis.—Stipes 2.5 cm or less in length, both curved into a spiral so they cross each other repeatedly, forming a succession of figure eights in flattened specimens. Axial angle very small; sicula unseen. Thecae number 7 or 8 in 5 mm (14 to 16 per cm), with strongly curved ventral walls and long thin genicular spines. Thecal apertures introverted.

Description.—Ruedemann originally described this form as a dicranograptid, but closer examination of the holotype and paratypes reveals the form to be actually a dicellograptid. Because of the extremely acute axial angle and nearly parallel initial portions of the stipes, he mistook the proximal part of the rhabdosome below the first stipe crossing for a biserial arrangement of thecae as in *Dicranograptus*. The following description is based on Ruedemann's type material from the Athens Shale at Pratt's Ferry, Alabama.

The largest rhabdosome is 19.5 mm long, and its stipes cross five times. The spiral habit of the stipes is revealed by the fact that the thecae almost always appear on the convex margin of the stipe in these flattened specimens. The spaces enclosed by the crossing stipes range from about 0.5 to 0.8 mm high in the most proximal space to as much as 5.0 mm high in the distal spaces. The stipes are 0.5 to 0.6 mm wide proximally and increase quickly to a maximum width of 0.7 mm. The thecae are not well preserved but appear to have strongly curved ventral walls and introverted apertures. The genicular spines are remarkably long (0.5 to 1.0 mm) and thin, and they occur along the entire length of the stipe.

Discussion.—The Alaskan specimens are only proximal fragments, but they possess the same dimensions and characteristic proximal end of *Dicellograptus bispiralis. D. bispiralis* resembles *D. caduceus* Lapworth in the crossing habit of its stipes but differs mainly in the fact that the stipe crossings of *D. bispiralis* are much closer together. *D. caduceus* also has spines only on the proximal thecae.

Occurrences.—Collections 69ACn547 and 69ACn549A; *Dicellograptus* Zone. With a fauna of approximately *Nemagraptus gracilis* Zone age in the Athens Shale near Pratt's Ferry, Alabama (Ruedemann, 1947). In south-central China (Wang and Jin, 1977).

Dicellograptus cf. *D. caduceus* Lapworth

Figures 31*D, F*

cf. *Dicellograptus caduceus* Lapworth, 1876a, pl. 4, fig. 83. Elles and Wood, 1901–1918, p. 161, pl. 23, figs. 4a–c, text figs. 102*a–c*.

Description.—The stipes are about 15 mm long and cross each other once to enclose an area about 1 cm long and 4 mm wide. They are about 0.6 to 0.7 mm wide and bear about 7 to 8 thecae in 5 mm. The thecae have strongly curved ventral walls with genicular spines and introverted apertural portions.

Discussion.—The Terra Cotta Mountains specimen matches *D. caduceus* in the crossing habit of its stipes (see Elles and Wood, 1901–1918, pl. 23, fig. 4c) and in the shape and spacing of its thecae, but its stipes are a bit narrower and it occurs with an older fauna.

Occurrences.—Collection 69ACn547; *Dicellograptus* Zone. *D. caduceus* occurs in the *Dicranograptus clingani* Zone (Hartfell Shales) of Scotland (Elles and Wood, 1901–1918) and the *D. caduceus* Zone (middle Caradocian) in Taimyr in the former USSR (Obut and Sobolevskaya, 1964).

Dicellograptus divaricatus divaricatus (Hall)

Figure 32*G*

Graptolithus divaricatus Hall, 1859, p. 513–514, figs. 1–4.
Dicellograptus divaricatus (Hall). Ruedemann, 1908, p. 296–299, pl. 18, figs. 3, 4; text figs. 212–214. Walters, 1977, p. 950, pl. 1, fig. C. Wang and Jin, 1977, p. 310, pl. 95, fig. 8. Strachan, 1986, p. 29, pl. 4, fig. 1.

Diagnosis.—Branches as much as 75 mm or more in length, generally straight but often with gentle flexure, widening rapidly from initial width of 0.6 mm to a maximum of 1 mm within 2 cm of their origins. Axial angle 60° to 90°. Sicula small, about 1.2 mm long, and generally pressed against one branch. Thecae number 9 to 11 per centimeter, with ventral margins straight and subparallel to axis of stipe. Apertures introverted, opening into semicylindrical excavations that occupy half the width of the stipe. Proximal thecae commonly bear short mesial spines or mucros.

Discussion.—The Alaskan specimen illustrated in figure 32*G* displays all the characters of *D. d. divaricatus* except for the proximal spines, and it also has a small web or membrane across the proximal part of the axil, similar to that illustrated by Ruedemann (1908, text fig. 214). *D. d. divaricatus* is distinguished from other dicellograptids by the shape of its thecae, the form of its rhabdosome, and the rapid widening of its branches.

Occurrences.—Collections 69ACn555 and 70ACn292; *Climacograptus bicornis* Zone. Normanskill Shale, New York (Hall, 1859; Ruedemann, 1908). Zones of *Nemagraptus gracilis* and *C. bicornis* (Woods Hollow Shale), Marathon region, Texas (Berry, 1960). Zone of *N. gracilis* in the St. Lawrence lowlands, Quebec (Walters, 1977), in the Shelve district, British Isles (Strachan, 1986), and in Taimyr in the former USSR (Obut and Sobolevskaya, 1964). Also found in China (Wang and Jin, 1977).

***Dicellograptus divaricatus salopiensis* Elles and Wood**

Figures 32*A–D*

Dicellograptus divaricatus var. *salopiensis* Elles and Wood, 1901–1918, p. 145–146, pl. 20, figs. 7a–e. Ruedemann, 1908, p. 300, pl. 18, figs. 5, 6. Ruedemann, 1947, p. 380, pl. 63, figs. 2, 3. Strachan, 1960, p. 50–53, pl. 1, figs. 1–5; pl. 2, fig. 1. Berry, 1960, p. 74, pl. 16, fig. 1. Ross and Berry, 1963, p. 104–105, pl. 6, figs. 21?, 24? Erdtmann, 1976, p. 90–91, pl. 5, fig. C/8C; pl. 7, fig. C/3B. Wang and Zhao, 1978, p. 628, pl. 203, fig. 5?

Dicellograptus sextans var. *exilis* Elles and Wood, 1901–1918, p. 155, pl. 21, figs. 2a–d, text fig. 97. Hadding, 1913, p. 55–56, text fig. 20. Ruedemann, 1947, p. 387, pl. 64, figs. 32, 33. Berry, 1960, p. 77, pl. 15, fig. 11. Ross and Berry, 1963, p. 107, pl. 6, figs. 7?, 15. Skwarko, 1962, p. 231, text-fig. 5, fig. 4?. Geh, 1963a, p. 82–83, pl. 1, figs. 11?, 12. Obut and Sobolevskaya, 1964, p. 42, pl. 6, figs. 8, 9. Tsai, 1976, p. 19–20, pl. 2, figs. 1–5. Wang and Zhao, 1978, p. 627, pl. 203, fig. 6?. Cooper, 1979, p. 85, pl. 17c, text fig. 70.

Dicellograptus salopiensis (Elles and Wood). Obut and Sobolevskaya, 1964, p. 41, pl. 6, fig. 7. Obut and Zubtzov, 1965, p. 25–26, pl. 3, figs. 1–3?. Tsai, 1976, p. 19, pl. 1, fig. 12. Strachan, 1986, p. 31, fig. 26, pl. 4, fig. 6.

Dicellograptus exilis Elles and Wood. Strachan, 1986, p. 31, pl. 4, fig. 5, pl. 5, fig. 13.

Diagnosis.—Stipes uniformly 0.5 mm wide throughout their length, straight or gently flexed. Thecae have approximately straight ventral walls, slightly introverted apertures, and number 12 to 10 per centimeter. Stipes 0.4 to 0.6 mm wide proximally and widening to about 0.75 mm at level of th5. Thecae number 15 per centimeter proximally and 12 per centimeter distally (Erdtmann, 1976).

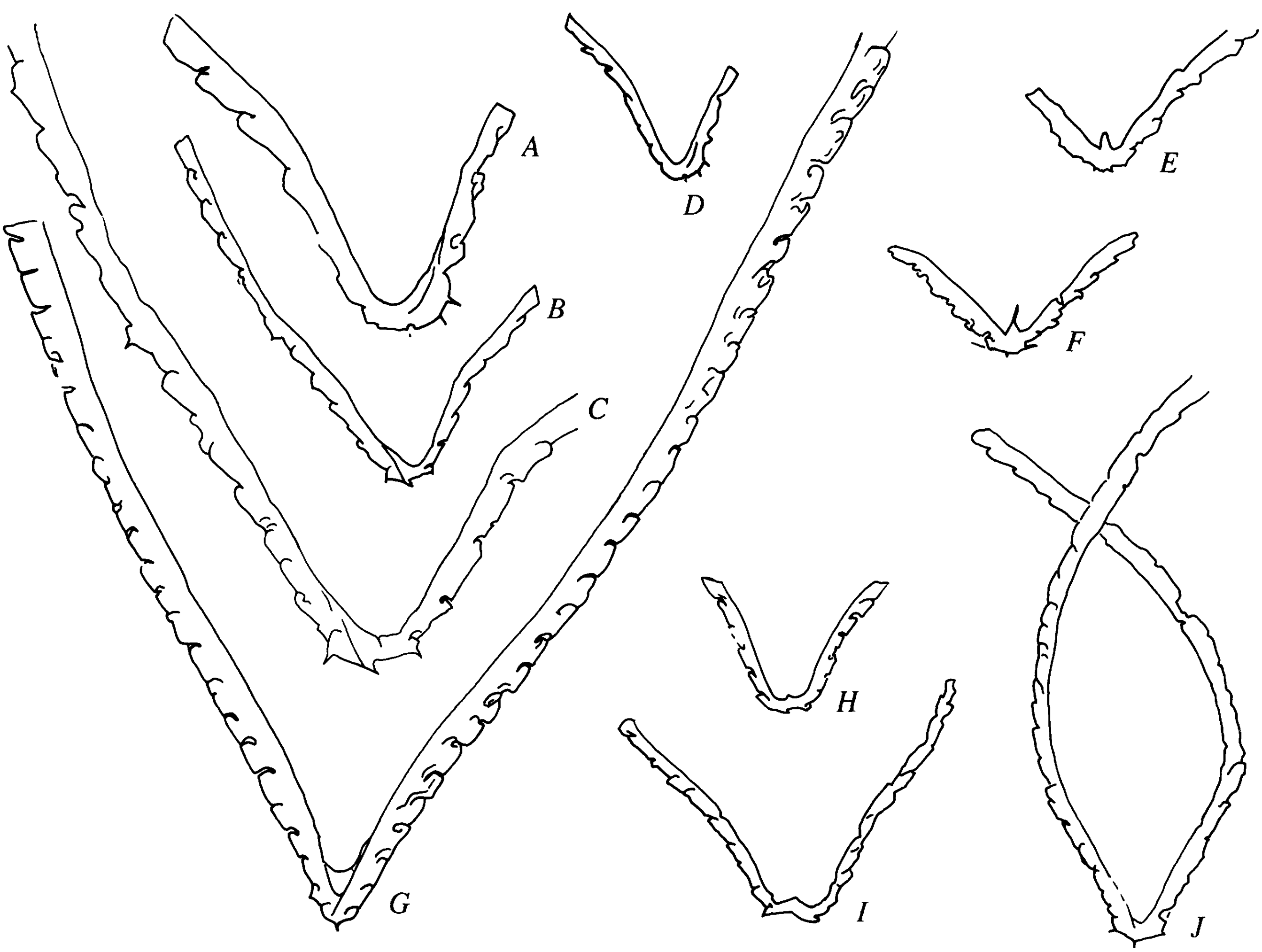


Figure 32. *Dicellograptus. **A–D**, D. divaricatus salopiensis* Elles and Wood, all from USGS colln. 69ACn556: ***A, D***, USNM 379088, ×10 and ×5, respectively; ***B, C***, USNM 379089, ×5 and ×10, respectively. ***E, F**, D.* aff. *D. flexuosus* Lapworth, USGS colln. 69ACn547, ×5: ***E***, USNM 379090; ***F***, USNM 379091. ***G**, D. divaricatus divaricatus* (Hall), USNM 379087, USGS colln. 70ACn292, ×5. ***H, I**, D.* sp. A, ×5: ***H***, USNM 379098, USGS colln. 69ACn575; ***I***, USNM 379099, USGS colln. 69ACn574. ***J**, D. gurleyi gurleyi* Lapworth, USNM 379092, USGS colln. 69ACn558, ×5.

Discussion.—In all of the Alaskan specimens, the sicula is in contact for its entire length with the dorsal margin of one of the stipes. The axil is U-shaped near the sicula, although, as a whole, the rhabdosome may be V-shaped. The sicula is about 1.5 mm long.

D. d. salopiensis is distinguished from *D. d. divaricatus* by the narrowness of its stipes. From other dicellograptids it is distinguished by the shape of its thecae and its uniformly narrow stipes.

Occurrences.—Collections 69ACn351, 69ACn547, 69ACn549A, 69ACn555, 69ACn556, 69ACn561, 70ACn62, and 70ACn411; *Dicellograptus* Zone and *Climacograptus bicornis* Zone. *D. d. salopiensis* is a well-known and widespread species, being found in the Zones of *Nemagraptus gracilis* and *C. bicornis* (and their equivalents) in Great Britain (Elles and Wood, 1901–1918; Strachan, 1960, 1986), North America (Ruedemann, 1908; 1947; Berry, 1960; Ross and Berry, 1963; Erdtmann, 1976), the former USSR (Obut and Sobolevskaya, 1964; Tsai, 1976), and China (Geh, 1963a; Wang and Zhao, 1978).

Dicellograptus aff. *D. flexuosus* Lapworth

Figures 32*E, F*

aff. *Dicellograpsus forchammeri* (Geinitz). Hopkinson, 1871, p. 23–24, pl. 1, figs. 1*a–d*.

aff. *Dicellograptus forchammeri* (Geinitz) var. *flexuosus* Lapworth, 1876b, pl. 4, fig. 90. Elles and Wood, 1901–1918, p. 152–153, pl. 22, figs. 2a–d, text figs. 95*a–d*. Ruedemann and Decker, 1934, p. 307–308, pl. 40, figs. 10, 10a, 11, pl. 41, figs. 1, 2. Ruedemann, 1947, p. 382, pl. 63, figs. 13–20.

aff. *Dicellograptus forchammeri* (Geinitz). Lapworth, 1876b, pl. 4, fig. 88. Elles and Wood, 1901–1918, p. 150–152, pl. 22, figs. 1a–d, text figs. 94*a–d*. Ruedemann and Decker, 1934, p. 307, pl. 40, figs. 9, 9a. Ruedemann, 1947, p. 382, pl. 63, figs. 9–12.

aff. *Dicellograptus flexuosus* Lapworth. Williams, 1982, p. 243, figs. 9a–e. VandenBerg and Stewart, 1983, p. 41, fig. 19. Bergström and Mitchell, 1986, figs. 7G, H, I. Finney, 1986, p. 452, figs. 8L, 9B, F.

Description.—The three Alaskan specimens are poorly preserved, with short stipes only 0.5 to 0.6 mm wide. The thecae appear to be of the *Dicellograptus flexuosus* type, with straight, inclined ventral walls and introverted apertural portions. The thecae are spaced about 12 per centimeter. The stipes are gently flexed and enclose an axial angle of about 90°. The sicula is conspicuous, measuring as long as 1.3 mm.

Discussion.—Because the stipes of the Alaskan specimens are truncated, their mature width cannot be determined, but they are close to *D. flexuosus* in their initial width (0.4 mm). They also resemble *D. flexuosus* in the size and shape of the sicula and the open axil. However, they occur at a lower horizon than *D. flexuosus*, which is found in the *D. clingani* and *P. linearis* Zones in the British Isles (Williams, 1982).

Occurrence.—Collection 69ACn547; *Dicellograptus* Zone

Dicellograptus gurleyi gurleyi Lapworth

Figures 32*J*, 33*A, B, E, F*

Dicellograpsus gurleyi Lapworth. Gurley, 1896, p. 70–71.

Dicellograptus gurleyi Lapworth. Ruedemann, 1908, p. 303–306, pl. 19, figs. 7–10, text figs. 223–228. Ruedemann, 1947, p. 382–383, pl. 63, figs. 21–33. Berry, 1960, p. 75, pl. 16, fig. 9. Ross and Berry, 1963, p. 105–106, pl. 6, figs. 14, 16, 18? Lenz and Chen, 1985, pl. 2, figs. 1–6, 14, 15, 17, 18.

not *Dicellograptus gurleyi* Lapworth. Ruedemann and Decker, 1934, p. 310, pl. 41, figs. 3–6a.

Diagnosis.—Stipes as much as 20 cm long, characteristically twisted into loose, opposite-turning spirals, forming a figure eight. Proximal axial region is rectangular, with initial axial angle of about 90°. Stipes first concave, then convex to the axil, measuring 0.5 mm at origin, soon widening to uniform width of 0.7 to 0.8 mm. Sicula 1.6 mm long, frequently free within the axial, but sometimes embedded in stipe, bearing short virgella. First 2 thecae subhorizontal, provided with short, lateral spines. Thecae have gently curved ventral walls and slightly introverted apertural portions; they number 9 to 12 per centimeter (averaging 10 per centimeter distally).

Discussion.—Almost all of the Alaskan specimens have the sicula embedded in one of the stipes, and they agree well with the above description. *D. g. gurleyi* is distinguished by the shape of its rhabdosome from most dicellograptids and by the shape of its thecae and axil from such species as *D. intortus* Lapworth and *D. caduceus* Lapworth.

Occurrences.—Collections 69ACn412, 69ACn557, 69ACn558, 69ACn562, and 70ACn62; *Climacograptus bicornis* Zone. Normanskill Shale, New York (Ruedemann, 1908). Viola Limestone, Oklahoma (Ruedemann and Decker, 1934). Zones of *Nemagraptus gracilis* and *C. bicornis* (Woods Hollow Shale), Marathon region, Texas (Berry, 1960), Nevada (Ross and Berry, 1963), and Peel River, northern Canadian Cordillera (Lenz and Chen, 1985).

Dicellograptus aff. *D. intortus* Lapworth

Figures 33*C, D*

aff. *Dicellograptus intortus* Lapworth, 1880, p. 161–162, pl. 5, figs. 19a–c. Ruedemann, 1908, p. 302–303, pl. 18, figs. 9, 10, text figs. 221, 222. Elles and Wood, 1901–1918, p. 146–147, pl. 20, figs. 4a–f, text figs. 90*a–d*. Ruedemann, 1947, p. 383–384, pl. 64, figs. 1–3. Berry, 1960, p. 75–76, pl. 15, fig. 1? Geh, 1963a, p. 84, pl. 1, figs. 14, 15?, 16. Obut and Sobolevskaya, 1964, p. 37–38, pl. 5, figs. 2–5. Tsai, 1976, p. 18, pl. 1, figs. 9, 10. Erdtmann, 1976, p. 91–92, pl. 6, fig. C/6c.

not *Dicellograptus intortus* Lapworth. Ross and Berry, 1963, p. 106, pl. 6, figs. 23, 25.

Description.—The stipes are greater than 3 cm long and increase very gradually in width from 0.5 mm near their origin to a maximum of 0.7 mm near their distal ends. Initially, the stipes enclose an axial angle of about 30°, but they

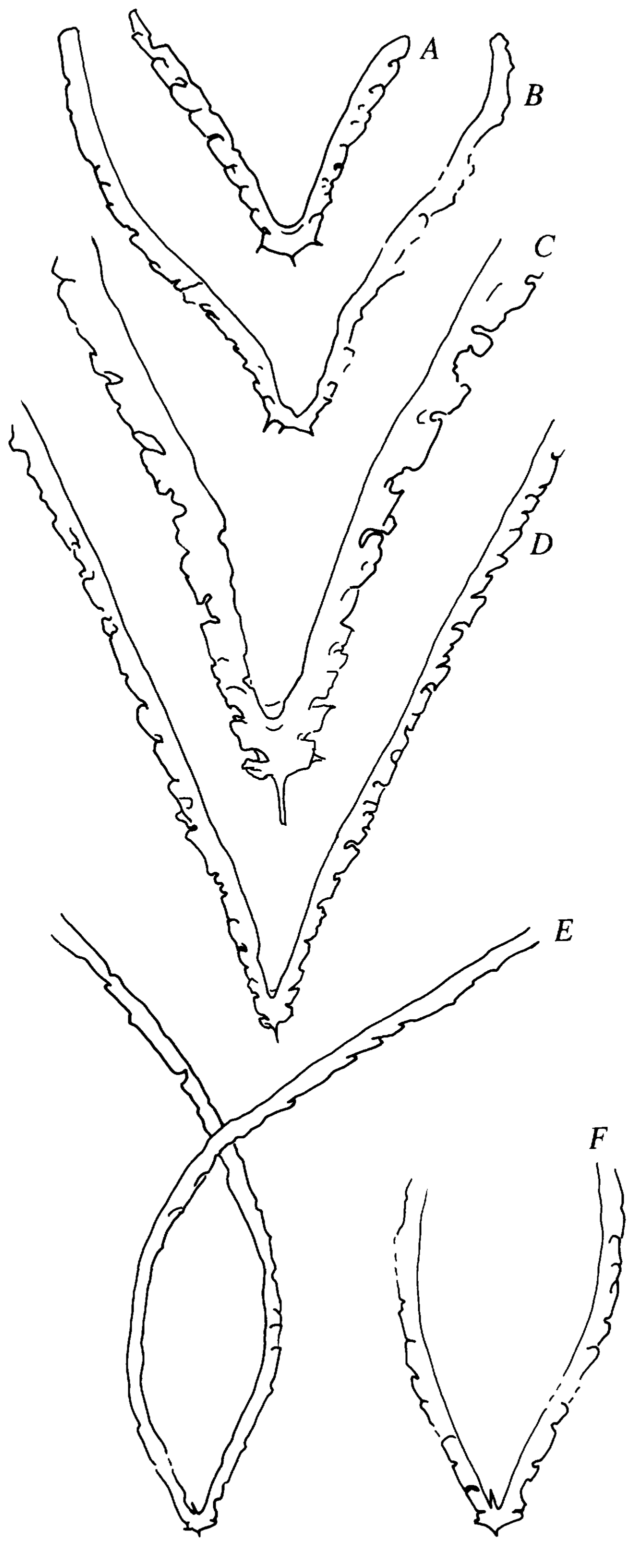


Figure 33. *Dicellograptus. **A, B, E, F**, D. gurleyi gurleyi* Lapworth: ***A***, USNM 379093, USGS colln. 69ACn557, ×5; ***B***, USNM 379094, USGS colln. 69ACn557, ×5; ***E, F***, USNM 379095, USGS colln. 69ACn558, ×3.5 and ×5, respectively. ***C, D**, D.* aff. *D. intortus* Lapworth, USNM 379097, USGS colln. 69ACn547, ×10 and ×5, respectively.

flex outward slightly about 4 mm from their origin, and the axial angle increases to about 50°. After this slight flexure, the stipes are straight. The thecae are of the *Dicellograptus intortus* type, with straight ventral walls nearly parallel to the stipe axis and introverted apertural margins. They number 13 to 11 per centimeter. The sicula is embedded in one of the stipes so that it cannot be distinguished within the axil, but it bears a conspicuous virgella 0.7 mm long. The axil appears to be bridged by a membrane or sheet of periderm in the manner of *D. d. divaricatus*.

Discussion.—The single specimen of this form resembles *D. intortus* in the shape of its proximal end, its small axial angle, and its thecae. It differs from *D. intortus* by having narrower stipes that do not cross or grow nearly parallel to each other as do those of *D. intortus*. From all other dicellograptids, this form can be distinguished by its narrow axil and the distinctive shape of the proximal end.

Occurrences.—Collection 69ACn547; *Dicellograptus* Zone. *D. intortus* sensu stricto occurs in the *Dicellograptus* and *Climacograptus bicornis* Zones in the Terra Cotta Mountains (see tables 1, 2). It also occurs in the *Glyptograptus teretiusculus* through (lower) *Diplograptus multidens* Zones in the British Isles (Elles and Wood, 1901–1918), the Normanskill Shale of New York, the Womble Shale of Arkansas, the Athens Shale of Alabama (Ruedemann, 1908; 1947), the *Nemagraptus gracilis* and *C. bicornis* Zones (Woods Hollow Shale) of Texas (Berry, 1960), the Exploits Group of Newfoundland (Erdtmann, 1976), the *N. gracilis* Zone in Victoria, Australia (VandenBerg, 1981), and equivalent horizons in the former USSR (Obut and Sobolevskaya, 1964; Tsai, 1976) and in China (Geh, 1963a).

Dicellograptus sp. A

Figures 32*H, I*

Description.—The stipes are 7 or 8 mm long and very narrow, only 0.3 to 0.4 mm wide initially, widening to a maximum of 0.5 mm, which is maintained for most of their length. The first 2 thecae grow subhorizontally and then the stipes bend abruptly, giving the axil a square appearance. Beyond this first bend, the stipes are slightly flexuous and enclose an angle of approximately 60° to 80°. The thecae number 6 to 8 in 5 mm and are of the *Dicellograptus divaricatus* type, with straight ventral walls. The sicula has not been fully preserved in any of the four Alaskan specimens.

Discussion.—This form has narrower stipes, more thecae per centimeter, and a squarer axil than *D. pumilus* Lapworth. It has more thecae per centimeter, and its stipes are wider and not as straight as those of *D. angulatus* Elles and Wood or *D.* cf. *D. angulatus* of Carter and Churkin (1977, p. 19, pl. 3, fig. 1). It has wider stipes and lacks the lateral spines of *D. minutus* Moors.

Occurrence.—Collections 69ACn574 and 69ACn575; *Climacograptus tubuliferus* Zone.

Family DIPLOGRAPTIDAE Lapworth, 1873
Genus *Diplograptus* McCoy, 1850
Diplograptus mucroterminatus Churkin and Carter

Figures 29*I*, *J*

Diplograptus mucroterminatus Churkin and Carter, 1970, p. 22–23, text figs. 9*A*, *B*, pl. 1, fig. 21. Ni, 1978, p. 396, pl. 1, fig. 22.

Diagnosis.—Rhabdosome short and relatively wide; about 15 mm long and 2.3 to 3.0 mm wide distally. Proximal end markedly tapers from a width of 0.6 to 0.9 mm at the first thecal pair to 2.0 to 2.6 mm at the fifth thecal pair. Thecae number 11 to 12 per centimeter; strongly climacograptid proximally, changing rapidly to orthograptid distally.

Discussion.—The Terra Cotta Mountains specimens have as few as 10 thecae per centimeter distally but otherwise closely agree with the above description. *D. mucroterminatus* is distinguished from other species of *Diplograptus* by its conspicuously tapered proximal portion.

Occurrences.—Collection 69ACn363; *Monograptus convolutus* Zone. Zone of *M. gregarius* (Descon Formation) in southeastern Alaska (Churkin and Carter, 1970). Zone of *Pristiograptus leei* (Lungmachi Formation) in the Yichang area, western Hubei, China (Ni, 1978). The range of *D. mucroterminatus* is thus extended upward by its occurrence in the Terra Cotta Mountains section.

Genus *Amplexograptus* Elles and Wood, 1907
Amplexograptus fallax Bulman

Figures 34*E*, *F*, *H–L*

Diplograptus perexcavatus Lapworth, 1880, p. 167, pl. 5, figs. 25D, E, ?25C, F, (not figs. 25A, B).
Diplograptus (*Amplexograptus*) *perexcavatus* Lapworth. Elles and Wood, 1901–1918, p. 267–269, text figs. 184*a*, *b*, *d*, pl. 31, fig. 15d (not text fig. 184*c*, pl. 31, figs. 15a–c).
Amplexograptus fallax Bulman, 1962, p. 463–465, text-figs. 2A–E. Tsai, 1976, p. 50, pl. 7, fig. 3. Strachan, 1986, p. 37, fig. 31.

Diagnosis.—Rhabdosome about 2 cm long, widening gradually from initial width of 0.8 mm at first pair of thecae to maximum of 1.6 to 1.9 mm (rarely 2 mm) at about 1.25 cm from proximal end. Thecae 8 to 9 in first 5 mm of length, 12 to 14 per centimeter distally. Apertural excavations about one-fourth of rhabdosome width. Supragenicular wall inclined distinctly outward; apertural margins nearly straight.

Discussion.—The Alaskan specimens differ from the above diagnosis only by being a bit wider (0.8 to 1.0 mm wide initially, 1.7 to 2.3 mm wide maximum) and having only 7 to 8 thecae in the first 5 mm of rhabdosome length. *A. fallax* resembles *A. perexcavatus* but is narrower and more gradually tapering and has differently shaped thecal excavations and supragenicular walls (see Bulman, 1962).

Occurrences.—Collections 69ACn351, 69ACn412, 69ACn555 through 69ACn559, 69ACn562, 70ACn62, 70ACn121, and 70ACn292; *Climacograptus bicornis* Zone. Lower Hartfell Shales (*C. wilsoni* Zone) and upper Glenkiln Shales (*C. peltifer* Zone) of Scotland (Bulman, 1962). Erkebidaikskiy horizon (*Diplograptus multidens* Zone), Kazakhstan (Tsai, 1976).

Amplexograptus n. sp.

Figures 34*A*, *B*, *G*

Description.—The long, tapering rhabdosome attains a length of more than 25 mm. It increases in width from 0.8 to 0.9 mm at the first pair of thecae, through 1.3 to 1.6 mm at the fifth thecal pair, to a maximum width of 2.7 to 3.5 mm at about 1.0 to 1.5 cm from the proximal end; thereafter it gradually narrows to a width of 2.0 to 3.0 mm. The thecae are of the amplexograptid type; they have outwardly inclined supragenicular walls and apertural excavations that occupy about one-fourth the width of the rhabdosome. The thecae are spaced at the rate of 7 in the first 5 mm of the rhabdosome and 10 to 11 per centimeter distally. The virgella is stout and conspicuous, measuring about 1.5 mm long.

Discussion.—This form is distinguished from most other species of *Amplexograptus* by its greater width. From *A. perexcavatus* (Lapworth) it differs in being more tapering and not so rapidly widening and it has fewer thecae per centimeter. *A. coelatus* (Lapworth) is wider initially (1.0 to 1.5 mm) and has fewer thecae per centimeter (10 to 8). *A.*? *ischimensis* Tsai has more thecae per centimeter distally (14) and its apertural excavations take up much less of the rhabdosome width.

Because we have only three complete specimens in the collection, this form has not been named, even though it is quite distinctive.

Occurrences.—Collection 69ACn568, *Climacograptus tubuliferus* Zone. A few specimens (figs. 34*C*, *D*) in collection 69ACn351 (*C. bicornis* Zone) resemble the above described form in general size, rhabdosome shape, and thecal spacing. They are a bit more narrow distally (0.8 to 1.0 mm wide proximally, 2.4 to 2.5 mm wide maximum), their thecal excavations are more prominent, and their supragenicular walls are not so outwardly inclined as those of specimens in the *Climacograptus tubuliferus* Zone.

Genus *Climacograptus* Hall, 1865
Climacograptus bicornis bicornis (Hall)

Figures 35*C*, *E*

Graptolithus bicornis Hall, 1847, p. 268–269, pl. 73, figs. 2*c*, *d*?, *e–h*, (not figs. 2*a*, *b*).
Climacograptus bicornis (Hall). Hall, 1865, pl. A, figs. 13, 14, 16, 17 (not fig. 15). Elles and Wood, 1901–1918, p. 193–195, pl. 26,

figs. 8a–f. Ruedemann, 1908, p. 80–85, pl. A, text figs. 12–17, p 433–437, text fig. 404 (not text fig. 405), pl. 28, figs. 24, 25 (not fig. 26). Ruedemann, 1947, p. 425, pl. 72, figs. 45, 46, 49–52 (not figs. 44, 47, 48). Berry, 1960, p. 79, pl. 16, fig. 10 (not fig. 11), pl. 19, fig. 4. Ross and Berry, 1963, p. 117–119, pl. 8, figs. 4–6, 9. Obut and Sobolevskaya, 1964, p. 51–53, pl. 10, figs. 1–8. Riva, 1974, p. 6–11, text-figs. 1A, B, pl. 1, figs. 1–3, 5–7. Riva, 1976, p. 595–605, text figs. 4–9. Erdtmann, 1976, p. 98–99, pl. 7 fig. C/7a. Lenz and Chen, 1985, pl. 4, figs. 2, 3. (See Riva, 1976, for a more complete synonymy.)

Diagnosis.—Rhabdosome as much as 10 cm or more in length, gradually widening from initial width of 0.7 to 0.9 mm to 1.8 to 2.3 mm at 2 cm from the proximal end, to as much as 2.5 to 3.0 mm distally. Thecae number 5 to 7 in first 5 mm of rhabdosome length and 8 to 9 per centimeter distally. Th1^1 and th1^2 bear prominent spines that increase in size as rhabdosome matures; frequently basal membranes of varying size and shape are developed on spines (see Riva, 1976, for detailed discussion.)

Discussion.—*C. b. bicornis* is well represented in the Terra Cotta Mountains faunas. In addition, a single specimen (fig. 35*E*) with a peculiar embellishment of the basal spines was found in association with a typical *C. bicornis* Zone fauna (collection 69ACn351) that included more than 20 specimens of *C. b. bicornis*. In this specimen, the basal spines bifurcate approximately 2 mm from their origin, and the two branches grow in nearly opposite directions. The spines appear to be thickened by enclosing membranes, as is common with *C. bicornis*. The rhabdosome of this specimen is more

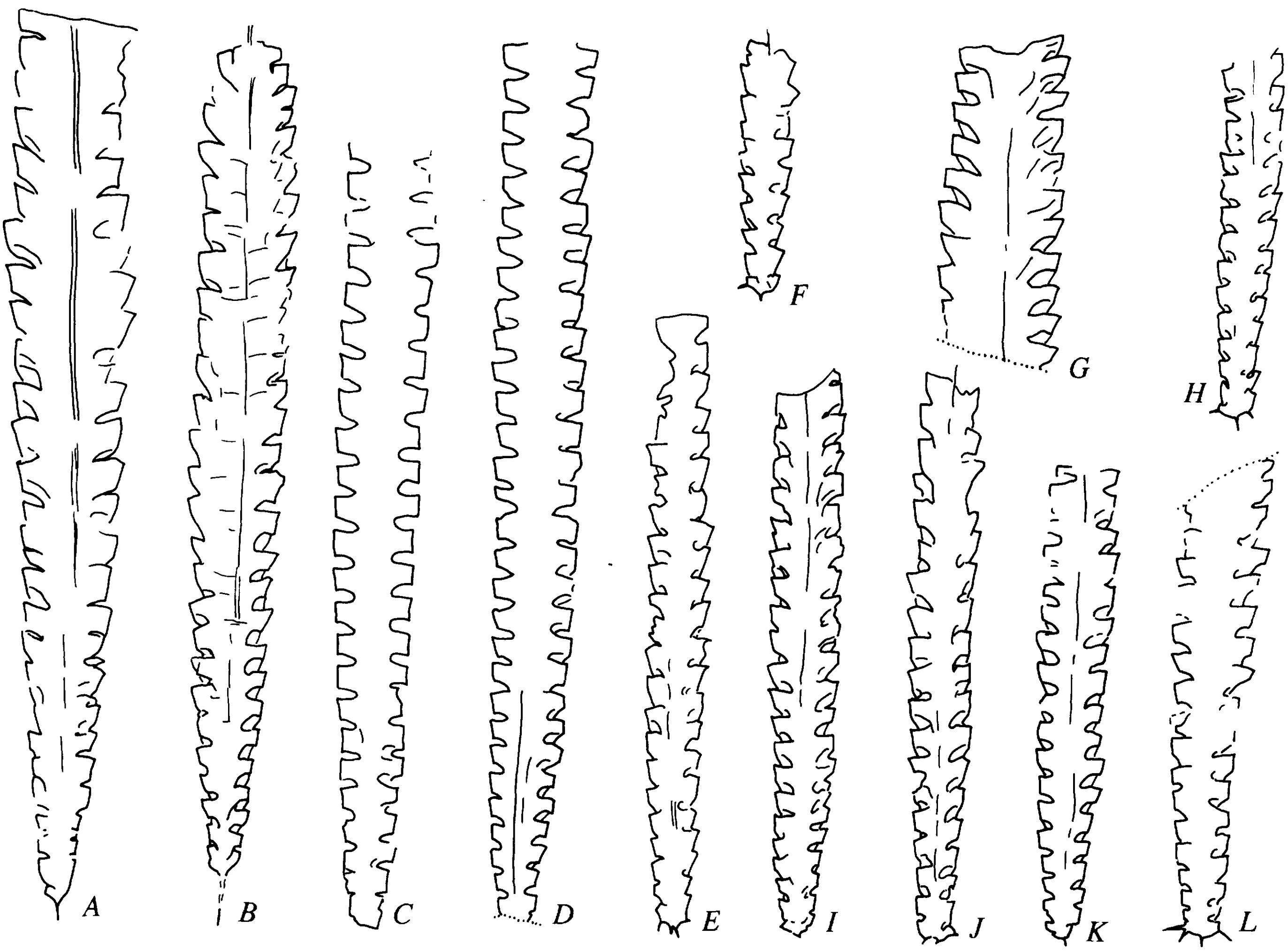


Figure 34. *Amplexograptus* (all ×5). ***A***, ***B***, ***G***, *A*. n. sp., all from USGS colln. 69ACn568: ***A***, USNM 379116; ***B***, USNM 379117; ***G***, USNM 379268. ***C***, ***D***, *A*. n. sp.?, all from USGS colln. 69ACn351: ***C***, USNM 379118; ***D***, USNM 379119. ***E***, ***F***, ***H–L***, *A. fallax* Bulman: ***E***, USNM 379109, USGS colln. 69ACn555; ***F***, USNM 379110, USGS colln. 69ACn555; ***H***, USNM 379111, colln. 69ACn555; ***I***, USNM 379112, USGS colln. 69ACn555; ***J***, USNM 379113, USGS colln. 69ACn555; ***K***, USNM 379114, USGS colln. 69ACn351; ***L***, USNM 379115, USGS colln. 69ACn557. Dotted line indicates edge of rock surface.

than 16 mm long, 1.0 mm wide just above the basal spines, and 2.2 mm wide at its distal end. The thecae are preserved in scalariform view and number 6 in 5 mm proximally and 5 in 5 mm distally. Thus, it matches the dimensions of *C. b. bicornis* and is here considered to be another variation of that rather variable species. The species *C. hsuei* Sobolevskaya (1969) and *C. venustus* Hsü (1959), which occur stratigraphically higher, exhibit somewhat similar, upward-growing processes on their downward-curving basal spines, but they differ significantly from the Terra Cotta Mountains specimen. The Terra Cotta Mountains specimen is probably only an isolated aberration and not a forerunner of these species.

Occurrences.—Collections 69ACn335, 69ACn351, 69ACn412, 69ACn554 through 69ACn558, 69ACn559A, 69ACn561 through 69ACn565, 70ACn51, 70ACn62, 70ACn121, 70ACn182, 70ACn183, 70ACn201, 70ACn411, 70ACn291, and 70ACn292; *C. bicornis* Zone. *C. b. bicornis* is a well-known and widespread species ranging through the *Nemagraptus gracilis* and *Diplograptus multidens* Zones or their equivalents (Riva, 1974; 1976).

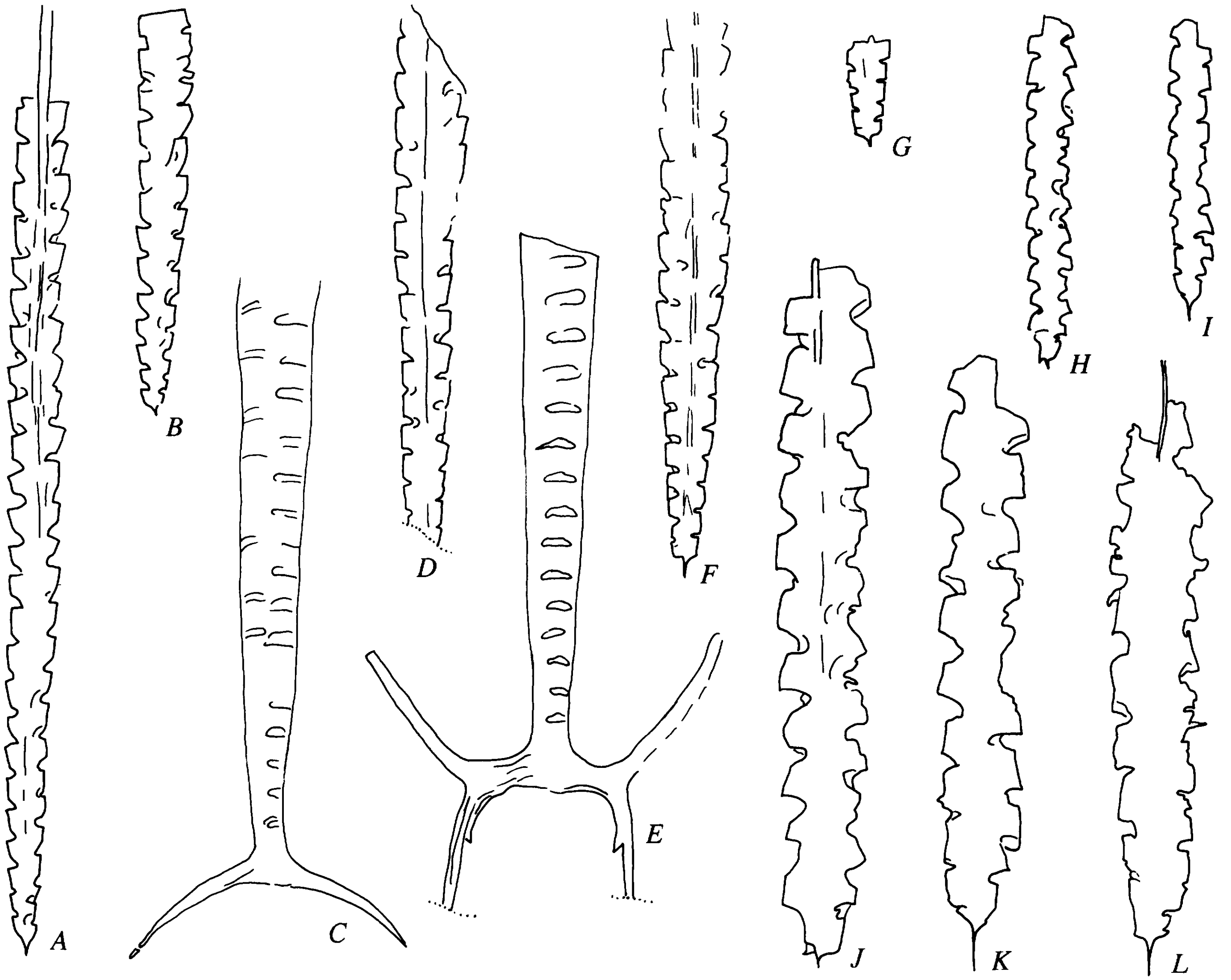


Figure 35. *Climacograptus* and *Pseudoclimacograptus*?. ***A, B***, *C.* aff. *C. tubuliferus* Lapworth, USGS colln. 69ACn573, ×5: ***A***, USNM 379122; ***B***, USNM 379123. ***C, E***, *C. bicornis bicornis* (Hall), USGS colln. 69ACn351, ×5: ***C***, USNM 379120; ***E***, USNM 379121. ***D, F, G***, *C.* sp. A, ×5: ***D***, USNM 379124, USGS colln. 69ACn549A; ***F***, USNM 379125, USGS colln. 69ACn552; ***G***, USNM 379126, USGS colln. 69ACn549A. ***H–L***, *P.*? cf. *P.*? *sculptus* Chen and Lin: ***H, J***, USNM 379127, USGS colln. 70ACn281, ×5 and ×10, respectively; ***I, K***, USNM 379128, USGS colln. 70ACn281, ×5 and ×10, respectively; ***L***, USNM 379129, USGS colln. 69ACn363, ×10. Dotted line indicates edge of rock surface.

Climacograptus aff. _C. tubuliferus_ Lapworth

Figures 35*A, B*

aff. *Climacograptus tubuliferus* Lapworth, 1876b, pl. 2, fig. 49. Elles and Wood, 1901–1918, p. 203–204, pl. 27, figs. 8a–d, text figs. 134*a–c*. Carter and Churkin, 1977, p. 23–24, pl. 7, fig. 5. Williams, 1982, p. 245–246, figs. 11a–n. (See Carter and Churkin, 1977, for more complete synonomy.)

Description.—The rhabdosome is as much as 25 mm long and widens gradually from 0.7 mm wide at th1^1 to a maximum width of 1.5 mm, which is attained 7 to 10 mm from the proximal end and is maintained thereafter. The thecae are climacograptid, with open, semicircular apertural excavations that occupy about one-fourth to one-third of the rhabdosome width; they number 6 in 5 mm proximally and 9 to 10 per centimeter distally. The virgula is wide and tubular as in *C. tubuliferus.*

Discussion.—The Terra Cotta Mountains form resembles *C. tubuliferus* in the shape and spacing of its thecae and thecal apertures, the initial width of its rhabdosome, and its membranous virgula. It differs in being considerably narrower distally (the maximum width of *C. tubuliferus* is 2.5 mm) and may actually represent a narrow subspecies of *C. tubuliferus*. It occurs in association with a specimen of *C. tubuliferus* that is only 1.9 mm wide.

Occurrence.—Collection 69ACn573; *C. tubuliferus* Zone.

Climacograptus sp. A

Figures 35*D, F, G*

Description.—The rhabdosome is as much as 24 mm long (usually shorter); at the first pair of thecae it is 0.7 to 0.8 mm wide, at the fifth thecal pair it is 1.2 to 1.3 mm wide, and it continues to widen gradually to a maximum width of 1.8 to 2.0 mm. The thecae are of the climacograptid type, numbering 6 to 7 in the first 5 mm of the rhabdosome and 9 to 10 per cm distally. The apertural excavations are relatively small, occupying about one-fourth the rhabdosome width. The first two thecae grow up along the rhabdosome so that their apertures face upward. The supragenicular walls are 0.5 to 0.6 mm long proximally (first four to five pairs) and 0.7 to 0.8 mm long distally. The proximal end is unadorned except for the virgella, which measures 0.5 mm long.

Discussion.—In general size and appearance, this form resembles *C. brevis mutabilis* Strachan. It is longer and wider distally than *C. b. mutabilis*, but Strachan's (1959) measurements were made on uncompressed material, making it difficult to compare the two. However, the Alaskan form is probably at least related to the *C. brevis* group.

Occurrences.—Collections 69ACn549, 69ACn549A, and 69ACn552; *Dicellograptus* Zone.

Genus _Pseudoclimacograptus_ Přibyl, 1947
Pseudoclimacograptus? cf. _P_.? _sculptus_ Chen and Lin

Figures 35*H–L*

cf. *Pseudoclimacograptus sculptus* Chen and Lin, 1978, p. 38, pl. 6, fig. 17, text figs. 8g, h. Ni, 1978, p. 397, pl. 1, fig. 13.

Description.—The rhabdosome is small, attaining a maximum length of 10 mm and a nearly uniform width of 1.2 to 1.3 mm. The width is 0.5 to 0.7 mm at the first pair of thecae and increases rapidly to about 1.2 mm at the third thecal pair, which is thereafter maintained. The thecae number $6^1/_2$ to 6 in 5 mm and are quite distinctively shaped in the flattened condition; they have pronounced genicula and inwardly inclined, straight or gently convex supragenicular walls. The thecal excavations are open and nearly semicircular, and the apertures are narrower than the overhanging infragenicular walls of the succeeding thecae.

Discussion.—The Alaskan specimens are flattened and poorly preserved; therefore the nature of the median septum is not discernible. On the basis of thecal shape (open excavations, inwardly inclined supragenicular walls) and overall rhabdosome size, they can be compared to *P.*? *sculptus*, although that species is only 1.0 mm wide and has 7 to 5 thecae in 5 mm. Both the Terra Cotta Mountains and Chinese forms are unusual for *Pseudoclimacograptus* and its subgenera *Metaclimacograptus* and *Pseudoclimacograptus* in that they possess nearly semicircular thecal excavations instead of the more usual slit-like excavations of the subgenera.

Occurrences.—Collections 69ACn363 and 70ACn281; *Monograptus convolutus* Zone. *P.*? *sculptus* occurs in the *Oktavites communis* Zone (approximately equivalent to the *M. convolutus* Zone of Great Britain) of Tongzi, northern Guizhou, China (Chen and Lin, 1978), and in the Lungmachi Formation (*M. sedgwickii* Zone) of the Yichang area, western Hubei, China (Ni, 1978).

Genus _Glyptograptus_ Lapworth, 1873.
Glyptograptus euglyphus (Lapworth)

Figures 36*G–I*, 37*C, G, H*

Diplograptus (*Glyptograptus*) *euglyphus* Lapworth, 1880, p. 166–167, pl. 4, figs. 14a–e. (?)Keble and Harris, 1934, p. 174–175, pl. 21, fig. 1. Ruedemann, 1908, p. 369–370, text figs. 315, 316, pl. 25, figs. 21–23. Ruedemann, 1947, p. 405–406, pl. 69, figs. 46–50, 55–59.

Diplograptus (*Glyptograptus*) *teretiusculus* var. *euglyphus* Lapworth. Elles and Wood, 1901–1918, p. 252, text fig. 172, pl. 31, figs. 2a–d. Berry, 1960, p. 88, pl. 15, fig. 8.

Glyptograptus euglyphus (Lapworth). Ross and Berry, 1963, p. 140, pl. 10, figs. 27, 28, pl. 11, figs. 3, 4. Geh, 1963b, p. 251, pl. 5, fig. 14. Berry, 1964, p. 146–147, pl. 15, figs. 1, 2. Obut and Sobolevskaya, 1964, p. 60–61, pl. 12, figs. 5–7. (?)Tsai, 1976, p. 44, pl. 6, figs. 8, 14. Lenz and Chen, 1985, pl. 3, figs. 4, 5.

Diagnosis.—Rhabdosome long (up to 10 cm) and narrow, tapering proximally; maximum width of 2.0 to 2.4 mm is maintained for most of its length. Thecae overlap less than one–third their length, are inclined about 40° to rhabdosome axis, with deep excavations, and number 11 to 7 per centimeter.

Discussion.—The Alaskan specimens are as much as 4.5 cm long and increase in width from 0.7 to 0.9 mm at the first thecal pair to 1.2 to 1.5 mm wide at the fifth thecal pair to a maximum width of 2.3 to 2.5 mm, which is attained about 1 to 1.5 cm from the proximal end. The thecae number 6 to 6½ in 5 mm proximally and 9 to 11 per centimeter distally. While many specimens have deep apertural excavations (fig. 36*G*), many are preserved in a slightly scalariform view so that the excavations do not appear to be as deep (figs. 36*H*, *I*).

In addition to specimens readily assigned to the species *G. euglyphus*, some narrower specimens in collection 69ACn542 resemble *G. euglyphus* in every way except their width (figs. 37*C*, *G*, *H*). They attain a maximum width of only about 1.7 mm approximately 1 cm from the proximal end, but, because they are otherwise so similar to *G. euglyphus*, they are assigned to the species.

Occurrences.—Collections 69ACn541, 69ACn542, and 69ACn543A, *Diplograptus*? *decoratus* Zone; and 69ACn551, *Dicellograptus* Zone. Zones of *G. euglyphus* and *Climacograptus bicornis* in northwestern Canada (Lenz and Chen, 1985). Glenkiln Shales (*Nemagraptus gracilis* Zone) of Scotland (Lapworth, 1880; Elles and Wood, 1901–1918). Normanskill Shale of New York (Ruedemann, 1947). Woods Hollow Shale (*N. gracilis* and *C. bicornis* Zones) in Texas (Berry, 1960). Vinini Formation (*Hallograptus etheridgei* to *Orthograptus truncatus intermedius* Zones) in Nevada (Ross and Berry, 1963). Darriwilian Zones of *D.*? *decoratus* and *G. teretiusculus* in Australia (VandenBerg, 1981). Also reported from Norway (Berry, 1964), China (Geh, 1963b), and the former USSR (Obut and Sobolevskaya, 1964; Tsai, 1976).

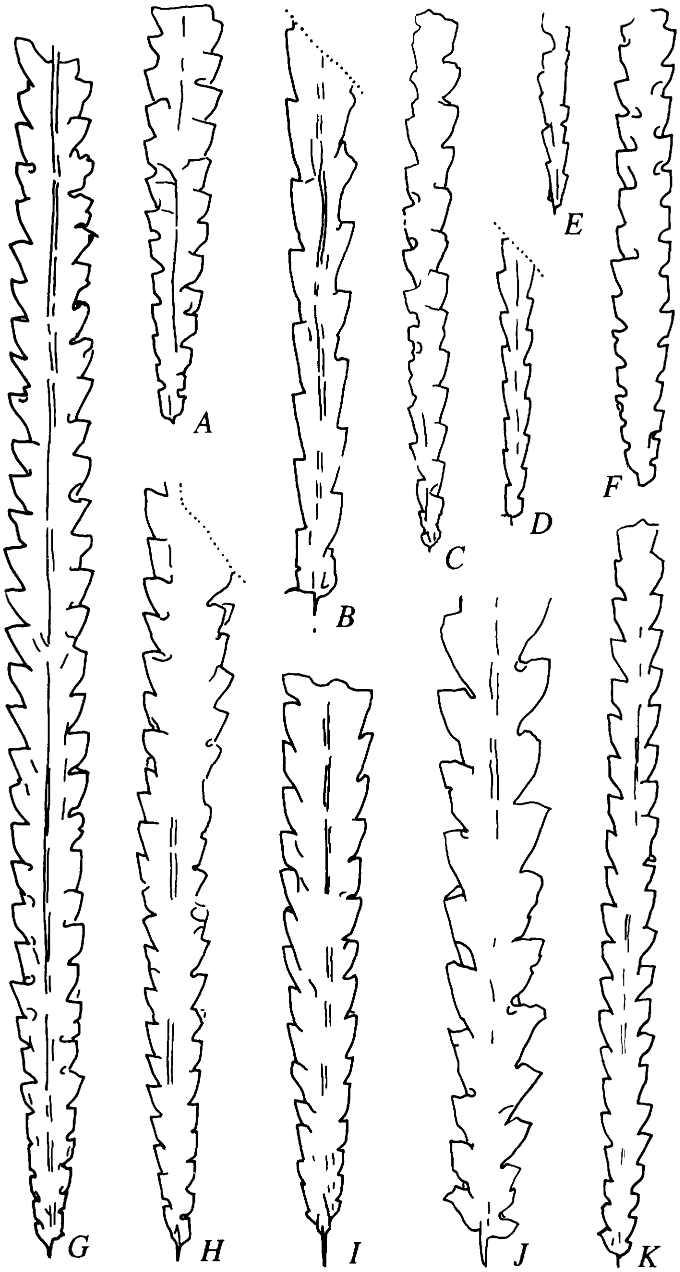


Figure 36. *Glyptograptus*. ***A***, *G.* cf. *G. incertus* (Elles and Wood), USNM 379133, USGS colln. 70ACn412. ×5. ***B***, ***D***, *G.* sp. A, USNM 379140, USGS colln. 69ACn541, ×10 and ×5, respectively. ***C***, ***E***, *G. tamariscus tamariscus* (Nicholson), USGS colln. 70ACn281, ×5: ***C***, USNM 379136; ***E***, USNM 379137. ***F***, *G.* sp. B, USNM 379141, USGS colln. 69ACn558, ×5. ***G–I***, *G. euglyphus* (Lapworth), all ×5: ***G***, USNM 379130, USGS colln. 69ACn541; ***H***, USNM 379131, USGS colln. 69ACn541; ***I***, USNM 379132, USGS colln. 69ACn542. ***J***, ***K***, *G. shelvensis* Bulman, USNM 379135, USGS colln. 69ACn541, ×10 and ×5, respectively. Dotted line indicates edge of rock surface.

Glyptograptus incertus (Elles and Wood)

Figure 37*B*

Diplograptus (*Glyptograptus*) *tamariscus* var. *incertus* Elles and Wood, 1901–1918, p. 249, text figs. 168*a*, *b*, pl. 30, figs. 9a–d.
Glyptograptus incertus Elles and Wood. Packham, 1962, p. 518–519, pl. 72, figs. 6, 7, text-figs. 4a–d. Churkin and Carter, 1970, p. 25–26, text figs. 10*D*, *E*, pl. 2, figs. 5, 6. (?)Wang and Zhao, 1978, p. 635, pl. 207, fig. 13. Chen and Lin, 1978, p. 25, pl. 3, figs. 6, 7. Chen, 1983, p. 35–36, pl. 1, figs. 8, 8a; pl. 2, fig. 1.
Glyptograptus (*G.*) *incertus* (Elles and Wood). Hutt, 1974, p. 25, pl. 3, fig. 3; pl. 4, figs. 12, 13; text-fig. 8, fig. 11.

Diagnosis.—Rhabdosome as much as 22 mm long, 0.6 to 0.8 mm wide at first pair of thecae, widening gradually to about 1.4 mm at 5 mm from proximal end, attaining a maximum width of about 1.6 mm. Thecae have distinct sigmoidal

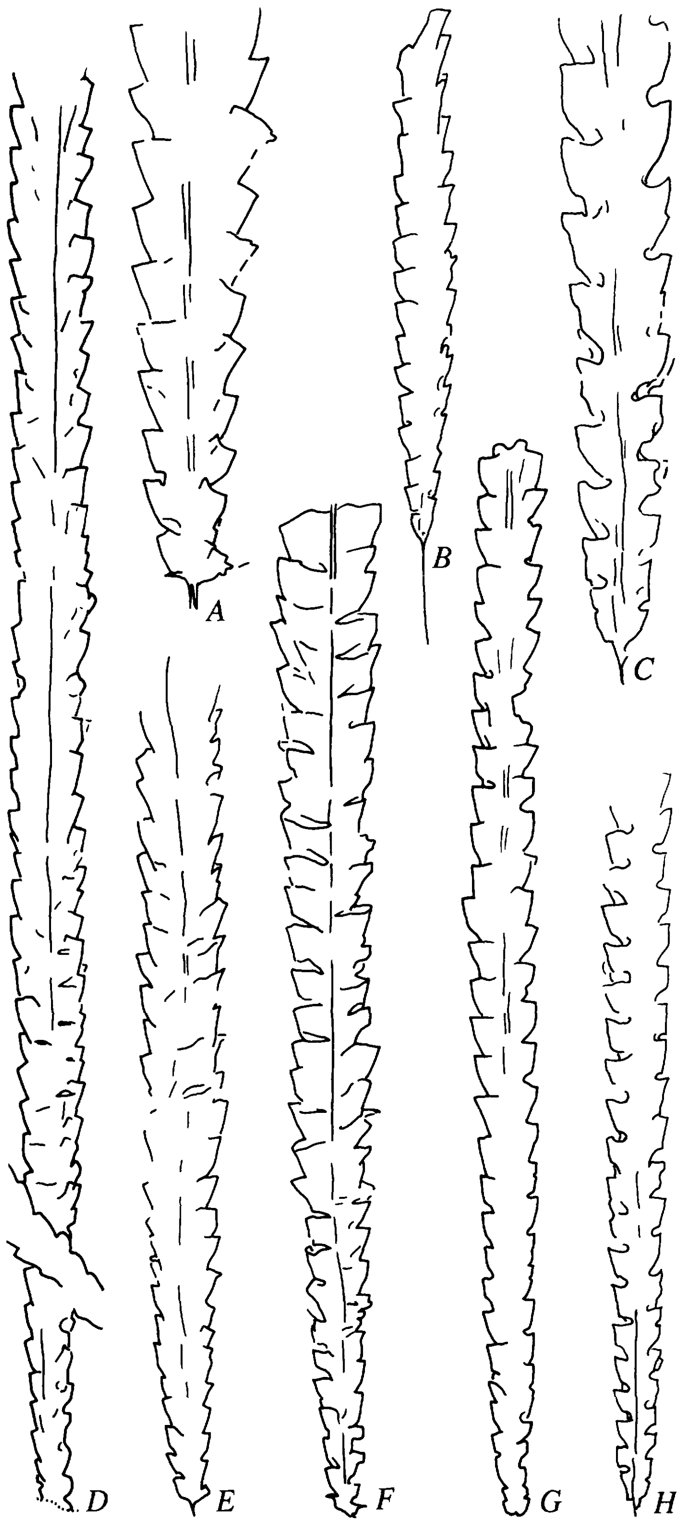


Figure 37. *Glyptograptus* and *Orthograptus*?. ***A, D–F***, *O.*? sp. A: ***A, E***, USNM 379142, USGS colln. 69ACn574, ×10 and ×5, respectively; ***D***, USNM 379143, USGS colln. 69ACn574, ×5; ***F***, USNM 379144, USGS colln. 69ACn576, ×5. ***B***, *G. incertus* (Elles and Wood), USNM 379134, USGS colln. 70ACn281, ×5. ***C, G, H***, *G. euglyphus* (Lapworth) (narrow form), all from USGS colln. 69ACn542: ***C, H***, USNM 379138, ×10 and ×5, respectively; ***G***, USNM 379139, ×5.

curvature, more pronounced proximally than distally, overlap about one-third their length, and number 12 to 10 per centimeter.

Discussion.—The illustrated specimen (fig. 37*B*) is preserved in subscalariform view so that the true depth of the apertural excavations cannot be seen. However, it agrees with *G. incertus* in dimensions and is here included in that species, even though it possesses an unusually long virgella.

A few specimens of *Glyptograptus* in collection 70ACn412 resemble *G. incertus* in general size and characteristics but attain a greater width distally (2.1 mm; fig. 36*A*) and are identified as *G.* cf. *G. incertus.*

Occurrences.—Collection 70ACn281, *Monograptus convolutus* Zone, and 70ACn423, mixed float, *M. sedgwickii* Zone. Birkhill Shales and Skelgill Beds (*M. convolutus* and *M. sedgwickii* Zones) in the British Isles (Elles and Wood, 1901–1918; Packham, 1962; Hutt, 1974). Descon Formation (*M. cyphus* Zone) in southeastern Alaska (Churkin and Carter, 1970). Lungmachi Formation (*Pristiograptus cyphus*—*Monoclimacis lunata* and *Demirastrites triangulatus* Zones) in northern Guizhou, China (Chen and Lin, 1978).

Glyptograptus shelvensis Bulman

Figures 36*J*, *K*

Glyptograptus shelvensis Bulman, 1963, p. 676–678, pl. 97, figs. 2, 3, 14, text-fig. 5. Strachan, 1986, p. 38, pl. 1, fig. 10.

Diagnosis.—Rhabdosome small and nearly parallel sided, about 1.5 cm long, widening from less than 1 mm (usually 0.8 to 0.9 mm) at $th1^1$ to maximum of 1.3 to 1.4 mm. Thecae of *G. dentatus* type, spaced about 6 in 5 mm (maximum range 11 to 14 per centimeter), with broad, low projections on ventral portions of apertural margins. $Th1^1$ and $th1^2$ bear delicate subapertural spines, and virgula is about 1 mm long.

Discussion.—The single Terra Cotta Mountains specimen is nearly 2 cm long but otherwise agrees well with Bulman's (1963) description. *G. shelvensis* resembles *G. dentatus* (Brongniart) in the shape of the thecae and the proximal end, but differs in its smaller size and more parallel-sided rhabdosome.

Strachan (1986) disputes Jenkins' (1980) contention that *shelvensis* is a species of *Undulograptus* that was incorrectly defined from distorted specimens. In keeping with the conservative approach of this paper, *shelvensis* is herein referred to *Glyptograptus*.

Occurrences.—Collection 69ACn541; lower *Diplograptus*? *decoratus* Zone. Shelve Church Beds (*Didymograptus extensus* Zone) and Skiddaw Slates (*Isograptus gibberulus* Subzone and *Didymograptus hirundo* Zone) in Great Britain and upper *G. dentatus* Zone in the northern Yukon Territory, Canada (Bulman, 1963).

Glyptograptus tamariscus tamariscus (Nicholson)

Figures 36*C*, *E*

Diplograpsus tamariscus Nicholson, 1868, p. 526, pl. 19, figs. 10, 11, ?13 (not fig. 12).
Diplograptus (*Glyptograptus*) *tamariscus* (Nicholson). Elles and Wood, 1901–1918, p. 247, pl. 30, fig. 8a (not figs. 8b–d), text figs. 167*a–c* (not fig. 167*d*).
Glyptograptus tamariscus tamariscus (Nicholson). Packham, 1962, p. 504–506, pl. 71, figs. 1–4, 11, 13, text-figs. 1g–j, m–u. Obut, Sobolevskaya, and Merkur'eva, 1968, p. 65–67, pl. 5, figs. 1–3. Rickards, 1970, p. 38, pl. 2, fig. 9, text-fig. 14, figs. 8, 13, 15. Golikov, 1973, p. 30–31, pl. 6, fig. 1. Chen and Lin, 1978, p. 23–24, pl. 3, figs. ?4, 5, text fig. 5c.
Glyptograptus (*G.*) *tamariscus tamariscus* (Nicholson). Hutt, 1974, p. 24, pl. 2, figs. 18–21, pl. 7, fig. 8.
not *Glyptograptus tamariscus* (Nicholson). Ross and Berry, 1963, p. 141, pl. 10, fig. 22.

Diagnosis.—Rhabdosome narrow and tapering, about 0.4 to 0.5 mm wide at aperture of $th1^1$, 0.7 to 0.9 mm wide at $th5^1$, and 0.9 to 1.3 mm wide maximum (in flattened specimens). Thecal excavations are deep and relatively long; thecae are alternating and number 12 to 14 per centimeter proximally and 8 to 12 per centimeter distally.

Discussion.—The Alaskan specimens closely agree with the above diagnosis. For a discussion of the several subspecies of *G. tamariscus*, see Packham (1962).

Occurrences.—Collections 69ACn363 and 70ACn281; *Monograptus convolutus* Zone. Zones of *Lagarograptus acinaces* through *M. sedgwickii* in the British Isles (Elles and Wood, 1901–1918; Packham, 1962; Rickards, 1970; Hutt, 1974). Lower Silurian beds in the former USSR (Obut and others, 1968; Golikov, 1973). Lungmachi Formation (*Demirastrites triangulatus* Subzone) in China (Chen and Lin, 1978). Road River Formation (*Atavograptus atavus–L. acinaces* Zones) in the Yukon Territory, Canada (Lenz and McCracken, 1982).

Glyptograptus sp. A

Figures 36*B*, *D*

Description.—The single rhabdosome is 7.5 mm long, 0.5 mm wide at $th1^1$, 0.75 mm wide at the aperture of $th5^1$, and 0.9 mm wide at the aperture of $th7^2$. The thecae are very gently sigmoidal, with almost no overlap, and they number about 11 per centimeter. The apertural excavations are shallow, and the supragenicular walls of the thecae are only slightly inclined (approximately 10°) to the rhabdosome axis.

Discussion.—The Terra Cotta Mountains specimen resembles the Silurian species *G. tamariscus* and its subspecies but differs in dimensions, thecal spacing, and the lesser amount of sigmoidal curvature of its thecae. From all other glyptograptids, it is distinguished by its extreme narrowness and the shape of its thecae.

Occurrence.—Collection 69ACn541; lower *Diplograptus*? *decoratus* Zone.

Glyptograptus sp. B

Figure 36*F*

Description.—The single specimen is 12 mm long and increases gradually in width from 0.7 mm wide at the aperture of $th1^1$ to a maximum of 1.5 mm at about $th6^1$. The thecae are strongly sigmoidal and geniculate (nearly climacograptid), numbering 12 to 11 per centimeter. The sicula appears to be free on one side for about 0.4 mm but is otherwise unknown.

Discussion.—This form is rather unremarkable in appearance. From most other glyptograptids, it is distinguished by its small, narrow rhabdosome and unadorned proximal end. It has fewer thecae per centimeter and its thecae are more geniculate than those of *G. euglyphus pygmaeus* Ruedemann. It is wider than *Climacograptus brevis* Elles and Wood.

Occurrence.—Collection 69ACn558; *Climacograptus bicornis* Zone.

Genus *Orthograptus* Lapworth, 1873

Orthograptus amplexicaulis intermedius (Elles and Wood)

Figures 38*A–C*

Diplograptus (*Orthograptus*) *truncatus* var. *intermedius* Elles and Wood, 1901–1918, p. 236, pl. 29, figs. 4a–e, text fig. 156. Ruedemann, 1947, p. 403–404, pl. 69, figs. 15?, 16?, 17?.
Orthograptus truncatus var. *intermedius* (Elles and Wood). Ross and Berry, 1963, p. 149–150, pl. 11, fig. 22?. Not Berry, 1960, pl. 17, figs. 4, 5.

Diagnosis.—Rhabdosome 8 to 13 cm or more in length, average width not exceeding 2.5 mm; maximum width attained within 2 cm of proximal end so that rhabdosome is parallel sided for greater part of its length. Thecae number 14 to 10 per centimeter, overlap one-half their length, are inclined at lower angle than those of *O. amplexicaulis amplexicaulis* (Hall); apertural margins less conspicuously everted.

Discussion.—The Alaskan specimens are 0.75 to 0.9 mm wide at the first pair of thecae and attain a maximum width of 1.7 to 2.2 (mostly about 2.0 mm). They have 14 thecae per centimeter proximally and 10 to 11 per centimeter distally, and the thecae are inclined about 20° to 30° to the rhabdosome axis.

In redescribing the species *O. amplexicaulis* (Hall), Riva (1974) included forms as narrow as 2.0 mm wide and gave the stratigraphic range as the Zones of *Climacograptus americanus* to *C. manitoulinensis* (approximately equivalent to the British Zones of *Dicranograptus clingani* through *Pleurograptus linearis*). However, it seems useful and proper to retain Elles and Wood's (1901–1918) subspecies *intermedius*—*O. truncatus* (Lapworth) is a junior synonym of *O. amplexicaulis* (see Riva, 1974, p. 32)—for the narrow forms (up to 2.5 mm wide) of *O. amplexicaulis* that first appear in the *C. bicornis* Zone and are therefore earlier than *O. amplexicaulis* sensu stricto.

Occurrences.—Collections 69ACn561, 69ACn562, 69ACn351, and 70ACn201; *C. bicornis* Zone. *C. wilsoni* and *Dicranograptus clingani* Zones (lower Hartfell Shales) in Scotland (Elles and Wood, 1901–1918). *O. truncatus intermedius* Zone in Texas (Berry, 1960) and Idaho (Ross and Berry, 1963).

Orthograptus cf. *O: calcaratus priscus* (Elles and Wood)

Figures 38*D–G*

cf. *Diplograptus* (*Orthograptus*) *calcaratus* var. *priscus* Elles and Wood, 1901–1918, p. 244–245, pl. 30, figs. 6a–c, text fig. 164.

Description.—The rhabdosome is short and broad, attaining a maximum length of 12 mm. It measures 1.3 to 1.5 mm wide at the aperture of $th1^1$, increases rapidly to a width of 3.0 to 3.5 mm at the fifth thecal pair, and reaches a maximum width of 4.0 to 4.5 mm at 5 to 7 mm from the proximal end. The thecae number 7 to 8 in 5 mm proximally and 12 per centimeter distally. They are straight tubes, measuring 0.6 to 0.9 mm wide, and are inclined about 20° to 30° to the rhabdosome axis. The proximal end is blunt, broad, and adorned only by a short virgella.

Discussion.—Some specimens exhibit a prominent internal framework of thickened lists (fig. 38*F*), and they may even appear clathriate at the distal end (figs. 38*D, F*). In this respect, they resemble *O. calcaratus grandis* (Ruedemann), which is, however, longer, wider, and much younger (Ashgillian).

The Terra Cotta Mountains form agrees with *O. calcaratus priscus* in its broad, blunt, proximal end, its broad rhabdosome, and its thecal spacing. However, it does not attain the great length (up to 12 cm) of *O. c. priscus* nor does it have the proximal lateral spines of *O. c. priscus*.

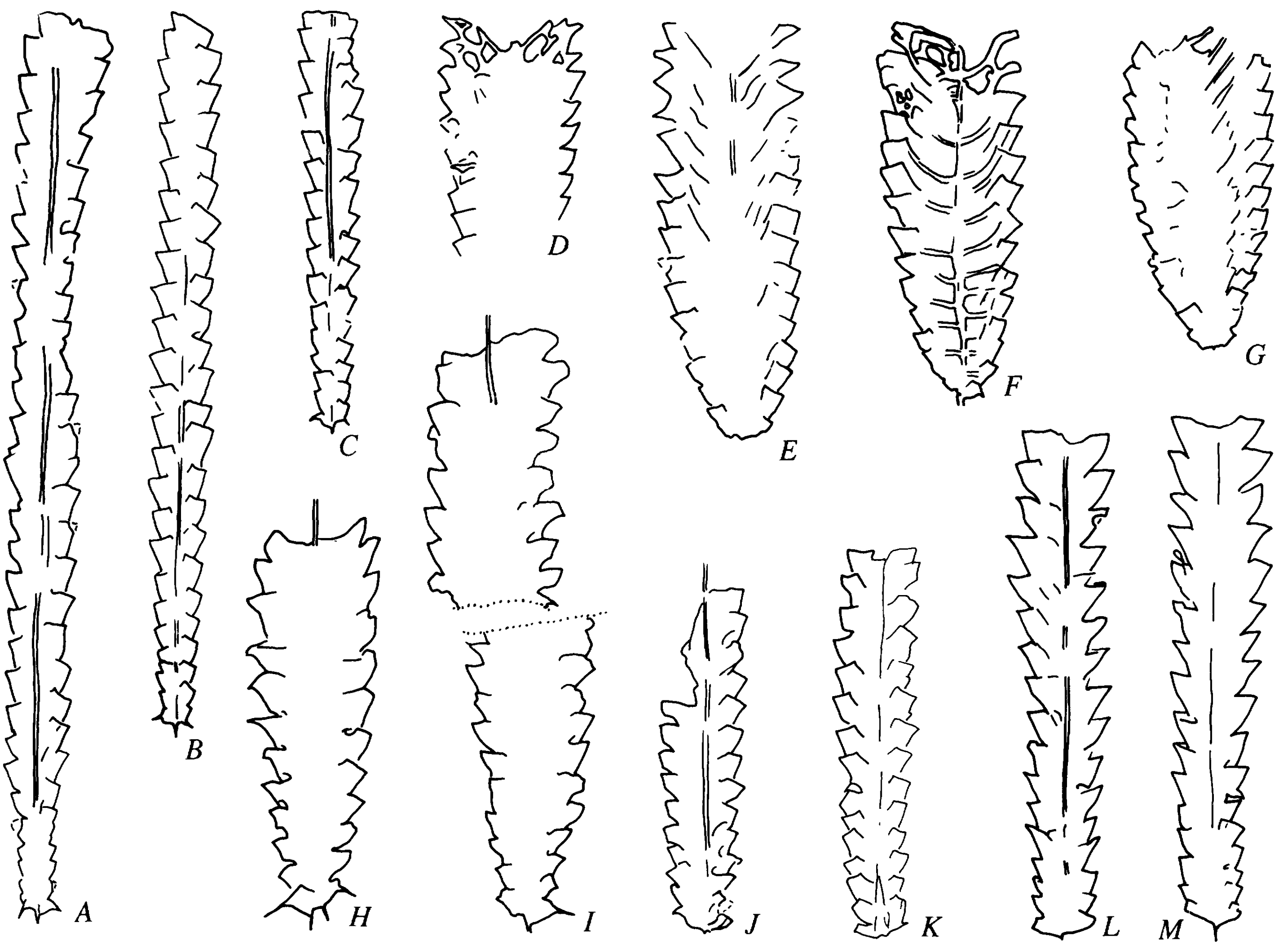


Figure 38. *Orthograptus* (all ×5). ***A–C***, *O. amplexicaulis intermedius* (Elles and Wood), all from USGS colln. 69ACn561: ***A***, USNM 379145; ***B***, USNM 379146; ***C***, USNM 379147. ***D–G***, *O.* cf. *O. calcaratus priscus* (Elles and Wood): ***D***, USNM 379148, USGS colln. 69ACn541; ***E***, USNM 379149, USGS colln. 69ACn541; ***F***, USNM 379150, USGS colln. 69ACn542; ***G***, USNM 379151, USGS colln. 69ACn541. ***H, I***, *O. calcaratus vulgatus*(Elles and Wood): ***H***, USNM 379152, USGS colln. 69ACn561; ***I***, USNM 379153, USGS colln. 69ACn557. ***J–M***, *O.*? n. sp.?: ***J***, USNM 379154, USGS colln. 69ACn552; ***K***, USNM 379155, USGS colln. 69ACn549A; ***L, M***, USNM 379156, part and counterpart, USGS colln. 69ACn574. Dotted line indicates break and offset of rock surface.

Occurrences.—Collections 69ACn541, 69ACn542, and 69ACn546; *Diplograptus*? *decoratus* Zone. *O. c. priscus* occurs in the Zones of *Didymograptus murchisoni* through *Diplograptus multidens* in the British Isles (Elles and Wood, 1901–1918).

Orthograptus calcaratus vulgatus (Elles and Wood)

Figures 38*H*, *I*

Diplograptus (*Orthograptus*) *calcaratus* var. *vulgatus* Elles and Wood, 1901–1918, p. 241–242, pl. 30, figs. 5a–d, text figs. 160*a–d*. ?Ruedemann, 1947, p. 401–402.

?*Orthograptus* cf. *O. calcaratus* var. *vulgatus* (Lapworth). Berry, 1960, p. 90–91, pl. 18, fig. 8.

Orthograptus calcaratus vulgatus (Elles and Wood). Geh, 1963b, p. 248, pl. 4, fig. 6. Erdtmann, 1976, p. 117–118, pl. 11, figs. B/7a, L/9d, L/11b. Strachan, 1986, p. 41, pl. 6, figs. 14, 16.

Diagnosis.—Rhabdosome like *O. calcaratus calcaratus* (Lapworth) but widens more rapidly and lacks large basal spines; 8 to 10 cm long, widens from 1 mm initially to 3 mm within 1 cm of proximal end and attains maximum width of 3.5 to 4.0 mm. Thecae number 12 to 8 per centimeter, have convex, everted apertural margins.

Discussion.—The Alaskan specimens conform almost exactly with Elles and Wood's wider illustrated specimen (1901–1918, text fig. 160*b*).

Occurrences.—Collections 69ACn557, 69ACn561, 69ACn562; *Climacograptus bicornis* Zone. *Diplograptus multidens* and *D. clingani* Zones in the British Isles (Elles and Wood, 1901–1918). Magog Shale of Quebec (Ruedemann, 1947). Zones of *Corynoides americanus* to *Climacograptus manitoulinensis* (Exploits Group) in Newfoundland (Erdtmann, 1976). *Nemagraptus gracilis* Zone (Miaopo Shale) in western Hubei, China (Geh, 1963b).

Orthograptus? sp. A

Figures 37*A*, *D–F*

Description.—The rhabdosome is long, as much as 4.5 cm in length, and its width increases gradually from initially about 0.8 to 1.0 mm, through 1.2 to 1.3 mm at the fifth thecal pair, to a maximum of 2.0 to 2.3 mm at 7 to 15 mm from the proximal end. The thecae appear to be slightly geniculate and inclined to the rhabdosome axis at a small angle (less than 15°); they are spaced 12 to 14 per centimeter proximally and 10 to 11 per centimeter distally.

Discussion.—This form has thecae that appear to be almost glyptograptid (that is, sigmoidal rather than straight) and have very shallow apertural excavations. It matches *Glyptograptus teretiusculus* (sensu Elles and Wood) in rhabdosome dimensions, thecal spacing, and the low angle of inclination of its thecae. However, the thecae of *G. teretiusculus* appear to be more sigmoidal, and their apertures are more concave and introverted. It is similar in size and thecal spacing to *O. amplexicaulis intermedius* (figs. 38*A–C*), and its proximal end is more orthograptid (wider, with shorter, spinose th1[1]) than glyptograptid (narrow, pointed, with single spine on sicula) in appearance, but its thecae are not as straight as those of *O. a. intermedius*.

Occurrences.—Collections 69ACn574, 69ACn575(?), 69ACn576; *Climacograptus tubuliferus* Zone.

Orthograptus? n. sp.?

Figures 38*J–M*

Description.—The rhabdosome is short and nearly parallel sided, with a relatively broad, blunt proximal end; it measures 1.3 to 1.5 mm wide at the first thecal pair, 1.5 to 2.0 mm at the fifth thecal pair, and 2.3 to 2.5 mm maximum. The thecae number 7 in 5 mm proximally and 12 to 9 per centimeter distally. The first two thecae grow subhorizontally for most of their length.

Discussion.—This form occurs at two widely separated horizons in the Terra Cotta Mountains section: The *Dicellograptus* and *Climacograptus tubuliferus* Zones. The lower-occurring (*Dicellograptus* Zone) specimens (figs. 38*J*, *K*) are only about 1 cm long, attain a maximum width of 2.3 mm, and have 14 to 12 thecae per centimeter. Their thecal apertural margins are distinctly everted. The *C. tubuliferus* Zone specimens (figs. 38*L*, *M*) are a bit longer (14 to 30 mm) and wider distally (2.5 mm), their distal thecae are more widely spaced (9 to 10 per centimeter), and their apertural margins are horizontal instead of everted.

Both forms exhibit the characteristic broad and squarish proximal end. This distinctive feature is reminiscent of the *Undulograptus austrodentatus* group, in which the first two thecae display a similar subhorizontal growth direction. The Terra Cotta Mountains form differs from *U. austrodentatus* and its subspecies in its straight thecae and unadorned (no lappets) apertural margins. From other orthograptids it may be distinguished by its nearly square proximal end and nearly parallel sided rhabdosome.

Occurrences.—Collections 69ACn549A, 69ACn552, 69ACn574; *Dicellograptus* and *C. tubuliferus* Zones.

Genus _Petalograptus_ Suess, 1851

Petalograptus palmeus palmeus (Barrande)

Figures 39*A*, *B*, *H*

Graptolithus palmeus var. *lata* Barrande, 1850, p. 61, pl. 3, figs. 3, 4 (not figs. 5–7).

Petalograptus palmeus (Barrande). Elles, 1897, p. 193–195, pl. 14, figs. 1, 2?, 3?, 4?. Elles and Wood, 1901–1918, p. 274, pl. 32, fig. 1d?, (not figs. 1a–c), text fig. 188*a* (not text fig. 188*b*). Bjerreskov, 1975, p. 33–34, pl. 4, fig. J. Chen, 1983, p. 45–46, pl. 4, figs. 14, 21. Not Churkin and Carter, 1970, p. 32, text fig. 13*G*, pl. 3, fig. 6.

Petalograptus palmeus var. *latus* (Barrande). Elles and Wood, 1901–1918, p. 275, pl. 32, figs. 2a, b (not figs. 2c–f).

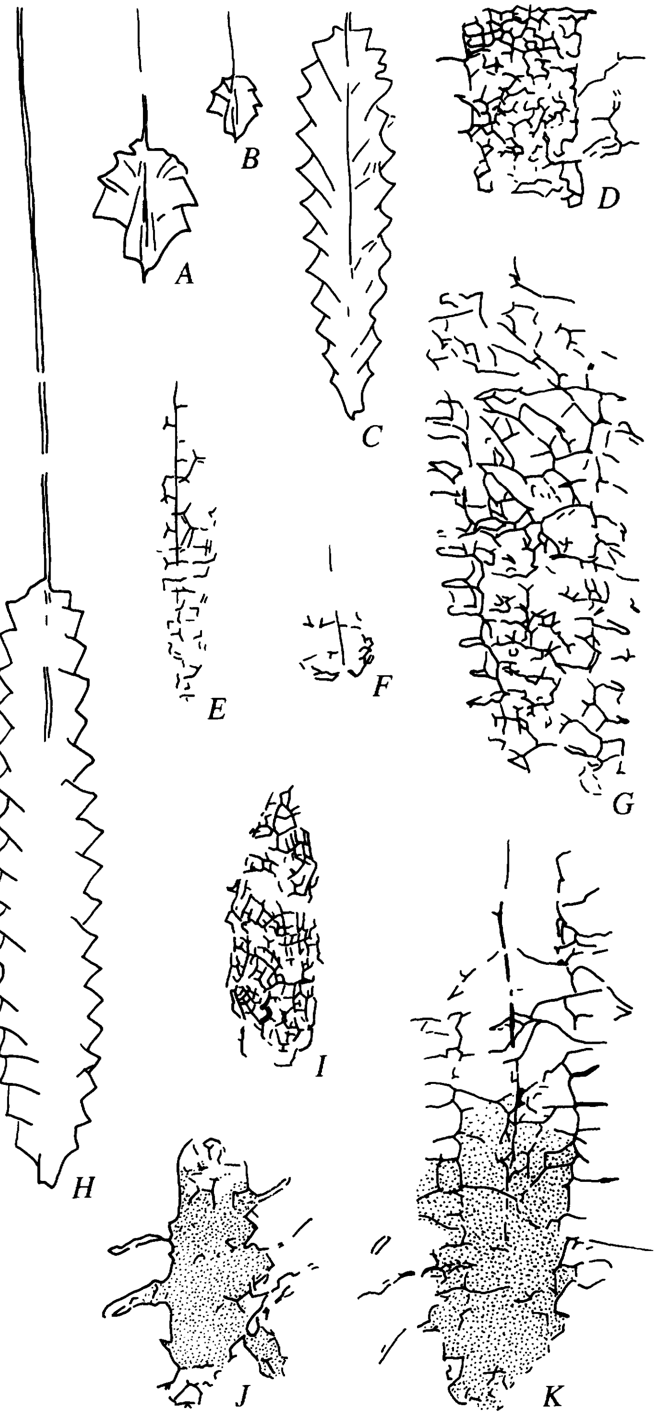
Petalolithus palmeus palmeus (Barrande). Bouček and Přibyl, 1941, p. 34, text fig. 1, figs. 1–3, pl. 1, figs. 1–3.

Diagnosis.—Rhabdosome approximately 20 mm long; width 1 to 2 mm (mostly about 1 mm) at aperture of $th1^1$, increases rapidly to 2.5 to 3.5 mm at fifth thecal pair; attains a maximum of 3 to 4 mm (sometimes less), and decreases distally by 0.5 to 0.9 mm. Sicula about 2 mm long, free on one side for about one-fourth its length. Thecae number 6 1/2 to 7 in 5 mm proximally, 10 to 12 per centimeter distally. First theca 0.8 to 1.5 mm long (measured from aperture to proximal end of rhabdosome).

Discussion.—The above dimensions were derived from measurements of illustrations of *P. palmeus* by Elles and Wood (1901–1918, pl. 32, figs. 2a, b; text fig. 188*a*). This species is not well defined and needs to be redescribed. It appears to be characterized by an elongated rhabdosome, 3 to 4 mm wide, with relatively short thecae, particularly at the proximal end.

The Terra Cotta Mountains specimen is 16 mm long, 1.5 mm wide at $th1^1$, 3.0 mm wide maximum (at th5), and decreases to 2.0 wide distally. It has 6 1/2 thecae in 5 mm proximally and 11 per centimeter distally. Its virgula is 15 mm long, and its first theca is 1.3 mm long.

Occurrences.—Collection 70ACn412; *Monograptus turriculatus* Zone. Zones of *Rastrites maximus* and *M. turriculatus* in the British Isles (Rickards, 1976). *Rastrites linnaei* Zone in the former Czechoslovakia (Bouček and Přibyl, 1941). *Spirograptus turriculatus* Zone (Nanjiang Formation of China (Chen, 1983). Lenz (1982) reports *P.* cf. *palmeus palmeus* from the *M. turriculatus* Zone in the Yukon Territory, Canada.



◄ **Figure 39.** *Petalograptus* and retiolitids. ***A, B, H***, *P. palmeus palmeus* (Barrande), USGS colln. 70ACn412: ***A, B***, USNM 379158, ×10 and ×5, respectively; ***H***, USNM 379159, ×5. ***C***, *P. praecedens* (Bouček and Přibyl), USNM 379160, USGS colln. 70ACn423, ×5. ***D***, *Retiolites* cf. *R. nevadensis* Berry and Murphy, USNM 379161, USGS colln. 69ACn423, ×10. ***E, F***, *Paraplectograptus*? sp., USGS colln. 76ACn292: ***E***, USNM 379165, ×5; ***F***, USNM 379166, ×10. ***G***, *Plectograptus* sp., USNM 379162, USGS colln. 69ACn423, ×10. ***I***, *Gothograptus* sp., USNM 379163, USGS colln. 70ACn91, ×5. ***J***, *Holoretiolites* (*Balticograptus*) cf. *H.* (*B.*) *lawsoni* Holland, Rickards, and Warren, USNM 379164, USGS colln. 69ACn423, ×10. ***K***, *Spinograptus*? sp., USNM 379167, USGS colln. 69ACn423, ×10.

Petalograptus praecedens (Bouček and Přibyl)

Figure 39*C*

Petalograptus palmeus (Barrande). Elles and Wood, 1901–1918, pl. 32, fig. 1b (not figs. 1a, c, d). Churkin and Carter, 1970, p. 32, text fig. 13*G*, pl. 3, fig. 6.

Petalolithus praecedens Bouček and Přibyl, 1941, p. 8–9, text fig. 2, figs. 12–15.

Petalograptus cf. *palmeus praecedens* (Bouček and Přibyl). Lenz, 1982, p. 21, fig. 2P.

Diagnosis.—Rhabdosome relatively short (maximum length about 1 cm), increasing in width to maximum of 2.3 to 2.5 mm. Thecae of *P. palmeus* type, spaced 13 to 12 per cm.

Discussion.—The Terra Cotta Mountains specimen is 10 mm long, 1.2 mm wide at the first pair of thecae, 2.0 mm wide at the fifth pair of thecae, and a maximum of 2.5 mm wide at about theca 7. The thecae are about 0.7 mm wide, 1.5 mm long, and number 6 in 5 mm. *P. praecedens* resembles

P. wilsoni Hutt and *P. tenuis* (Barrande) but is wider and has longer thecae than they do

Occurrences.—Collection 70ACn423 (mixed float); *Monograptus convolutus* Zone. Zones of *M. gregarius* to *M. convolutus* (Descon Formation) in southeastern Alaska (Churkin and Carter, 1970); equivalent horizons in northern Canadian Cordillera (Lenz, 1982). *M. convolutus* Zone (Birkhill Shales) in Scotland (Elles and Wood, 1901–1918). *M. sedgwickii* Zone in the former Czechoslovakia (Bouček and Přibyl, 1941).

Family RETIOLITIDAE Lapworth, 1873
Genus *Retiolites* Barrande, 1850
***Retiolites* cf. *R. nevadensis* Berry and Murphy**

Figure 39*D*

cf. *Retiolites nevadensis* Berry and Murphy, 1975, p. 100, pl. 15, figs. 5, 6. Lenz, 1978, p. 636, pl. 7, figs. 1, 2, 6.

Description.—The single fragmentary specimen is 1.5 mm wide, excluding spines, and exhibits the rather finely spun reticulum and apertural spines characteristic of *R. nevadensis*. The clathria cannot be readily distinguished.

Discussion.—Because the specimen is so fragmentary, it cannot be conclusively identified, but it matches *R. nevadensis* in the very fine meshwork of its reticulum.

Occurrences.—Collection 69ACn423; approximately *Monograptus ludensis* Zone. *R. nevadensis* is found in the *Cyrtograptus perneri* and *Monograptus testis* Zones (Roberts Mountains Formation) in central Nevada (Berry and Murphy, 1975) and in the uppermost Wenlockian beds in northern Canada (Lenz, 1978).

Genus *Plectograptus* Moberg and Törnquist, 1909
***Plectograptus* sp.**

Figure 39*G*

Description.—The rhabdosome is more than 8 mm long and 1.3 to 1.8 mm wide, excluding the apertural lists. The reticulum is irregular and well developed, and the virgula is absent. The thecae are defined by lower and upper apertural lists and number about 13 per centimeter.

Discussion.—This form resembles *P. macilentus* (Törnquist) in its looping apertural lists connected by a mesial transverse list, but it lacks the regular, subhexagonal clathria and virgula of *P. macilentus*. It resembles *P.? bouceki* Rickards and *P. textor* Bouček and Münch in its irregular reticulum and lack of a virgula, but differs from them in the characters of the apertural lists.

Occurrence.—Collection 69ACn423; approximately *Monograptus ludensis* Zone.

Genus *Gothograptus* Frech, 1897
***Gothograptus* sp.**

Figure 39*I*

Discussion.—The few specimens are so fragmentary that they cannot be identified as to species with any certainty. The figured specimen is only 2.5 mm long and 0.8 mm wide, and the thecae cannot be clearly distinguished. However, the finely spun reticulum and distally tapering shape of the rhabdosome indicate a probable close relationship to *Gothograptus nassa* (Holm).

Occurrence.—Collection 70ACn91; *Monograptus digitatus* Zone.

Genus *Holoretiolites* Eisenack, 1951
Subgenus *Balticograptus* Bouček and Münch, 1952
Holoretiolites (Balticograptus)* cf. *H. (B.) lawsoni
Holland, Rickards, and Warren

Figure 39*J*

cf. *Holoretiolites (Balticograptus) lawsoni* Holland, Rickards, and Warren, 1969, p. 666–668, text-figs. 1a–c.

Description.—The tiny rhabdosome is only 3.5 mm long and 1.0 to 1.2 mm wide, excluding the apertural processes, which are 0.5 to 0.9 mm long. By extrapolation, the thecae number 7 to 8 in 5 mm. The clathrial elements are hard to see, and the rhabdosome appears to have some sort of peridermal material filling the clathria.

Discussion.—The single specimen has been somewhat broken and distorted on burial, but it is the same size as *H. lawsoni* and has similar, loop-shaped apertural processes. It seems to lack the internal clathrial elements of *H. lawsoni* and the cross threads inside the loops of the apertural processes. *H. (B.) lawsoni* is distinguished from other species of *Balticograptus* by its longer apertural processes and the size of its rhabdosome and thecal spacing.

Occurrences.—Collection 69ACn423; approximately *Monograptus ludensis* Zone. *H. (B.) lawsoni* occurs in the *M. ludensis* Zone (Wenlock Shale) in England (Holland and others, 1969).

Genus *Paraplectograptus* Přibyl, 1948
***Paraplectograptus*? sp.**

Figures 39*E, F*

Description.—The rhabdosome is as much as 8 mm long and about 1.5 mm wide at its widest point. The virgula is incorporated into one wall of the rhabdosome and is attached by alternating horizontal lists to the zigzagging pleural lists. The thecae number approximately 11 per centimeter.

Discussion.—None of the Terra Cotta Mountains specimens are well-enough preserved to allow determination of the nature of the anterior (nonvirgular) wall. However, the transverse lists running from the virgula out to the apertural edges of the rhabdosome can be clearly seen, and this feature is characteristic of the genus *Paraplectograptus*. The Alaskan specimens are very nearly the same size as *P. eiseli* (Manck) (1.5 mm wide, 9 to 10 thecae per centimeter) but are not well enough preserved for more than tentative identification.

Occurrence.—Collection 76ACn292; *Cyrtograptus sakmaricus–C. laqueus* Zone.

Genus *Spinograptus* Bouček and Münch, 1952
Spinograptus? sp.

Figure 39*K*

Description.—The single specimen is 7.5 mm long, 1.3 to 1.5 mm wide (excluding spines), and has 11 to 10 thecae per cm. The spines on the ventral margins of the rhabdosome measure 1.0 mm or more in length; half of the spines are presumed to be apertural and the other half appear to be located close to midway between the apertural spines. The clathria forms an irregular network on the wall of the rhabdosome and appears to support some sort of infilling periderm in the proximal half.

Discussion.—Because of the poor preservation of the only specimen at hand, the morphologic details of this form are unclear. It differs from *S. spinosus* mainly by the presence of a second set of ventral spines between the apertural(?) spines. It differs from *Pseudoplegmatograptus* by lacking a finely spun reticulum and well-developed lacinia. From all other retiolitids, it is distinguished by its ventral spines.

Occurrence.—Collection 69ACn423; approximately *Monograptus ludensis* Zone.

Family MONOGRAPTIDAE Lapworth, 1873
Genus *Monograptus* Geinitz, 1852
Monograptus decipiens valens (Přibyl and Münch)

Figures 40*A–I*

Monograptus decipiens Törnquist. Elles and Wood, 1901–1918, pl. 47, figs. 3c, d (not figs. a, b, e), text fig. 325*c* (not text fig. *a*, *b*).
Demirastrites decipiens valens Přibyl and Münch, 1942, p. 14–15, text fig. 1, fig. 8; pl. 1, fig. 11. Golikov, 1973, p. 43, pl. 9, figs. 3, 5, 7–9, pl. 10, figs. 1, 3–7.
?*Demirastrites valens* (Přibyl and Münch). Mu and Ni, 1975, p. 16, pl. 2, fig. 1.
Monograptus decipiens valens (Přibyl and Münch). Lenz, 1982, p. 75–76, figs. 6G, J, L; 23B, D, E, G.

Diagnosis.—Rhabdosome moderately to strongly curved proximally, less so distally, with thecae on convex margin except distally where stipe may undergo torsion. Width of rhabdosome increases from 0.5 mm at aperture of th1 to maximum of 1.6 to 1.9 mm. First 2 to 3 thecae rastritiform, inclined at 30° to 40° to dorsal margin of stipe, weakly triangular in profile, with hooked apertural ends. Distal thecae triangular and hooked; amount of overlap increases distally from

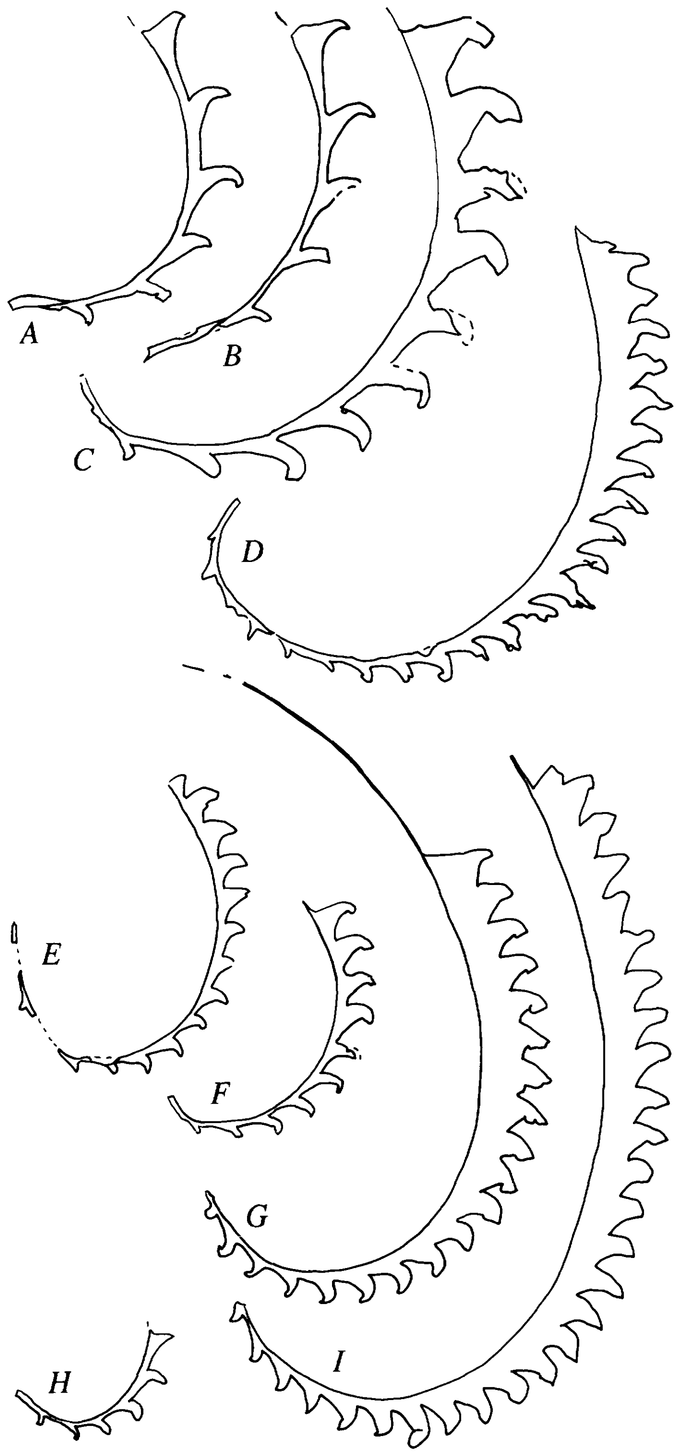


Figure 40. *Monograptus decipiens valens* (Přibyl and Münch), all from USGS colln. 70ACn412. ***A***, ***H***, USNM 379168, ×10 and ×5, respectively; ***B***, USNM 379169, ×10; ***C***, ***F***, USNM 379170, ×10 and ×5, respectively; ***D***, USNM 379171, ×5; ***E***, USNM 379172, ×5; ***G***, USNM 379173, ×5; ***I***, USNM 379174, ×5.

almost none to maximum of about one-half the length. Thecae number 9 to 10 per centimeter. Sicula 1.1 to 1.2 mm long, weakly ventrally curved.

Discussion.—In many of the Alaskan specimens, the slender proximal portion of the rhabdosome is missing, probably because it was extremely thin (common canal less than 0.2 mm wide) in comparison to the rest of the stipe, and thus subject to breakage. *M. d. valens* is wider than *M. d. decipiens*, has fewer rastritiform thecae, and has more overlap of the distal thecae. It resembles *M. planus* (Barrande) in the appearance of the distal thecae but differs mainly in having rastritiform proximal thecae.

Occurrences.—Collections 70ACn152, 70ACn202, 70ACn412 and 70ACn423; *M. turriculatus* Zone. *M. sedgwickii* and *M. turriculatus* Zones (Road River Formation) in the Yukon Territory, Canada (Lenz, 1982). *M. sedgwickii* Zone in Germany (Přibyl and Münch, 1942) and *Spirograptus minor* Zone in south-central part of the former USSR (Golikov, 1973).

Monograptus delicatulus Elles and Wood

Figures 41*A*, *B*

Monograptus delicatulus Elles and Wood, 1901–1918, pl. 478, pl. 47, figs. 2a, b, text fig. 333. Hutt, 1975, p. 87–88, text-fig. 21, fig. 1. Rickards and others, 1977, p. 104, fig. 38.

?*Demirastrites delicatulus* (Elles and Wood). Obut and others, 1968, p. 109–111, pl. 30, figs. 3–8, pl. 31, figs. 1–5. ?Sennikov, 1976, p. 213–214, pl. 15, figs. 4, 5.

Diagnosis.—Rhabdosome slender, coiled into irregular spiral, with thecae on convex margin, increasing gradually in width until maximum of about 1.0 mm is reached. Thecae number 10 per centimeter, without overlap, triangular and hooked throughout length of rhabdosome.

Discussion.—*M. delicatulus* resembles *M. convolutus* (Hisinger), but it lacks the rastritiform proximal thecae and is more delicate in overall appearance. It differs from *M. involutus* Lapworth in the more spinose character of its thecae.

Occurrences.—Collection 70ACn423 (mixed float); associated with a fauna characteristic of the *M. sedgwickii* Zone. Zones of *M. triangulatus* through *M. sedgwickii* in the British Isles (Elles and Wood, 1901–1918; Hutt, 1975; Rickards, 1976). ?Zone of *Demirastrites triangulatus* in western Siberia (Obut and others, 1968; Sennikov, 1976).

Monograptus digitatus n. sp.

Diagnosis.—Rhabdosome broadly arcuate to nearly straight, with thecae on convex margin. Proximal 1 to 8 thecae are isolated tubes of rastritiform type; distal thecae are pristiograptid. Sicula ventrally curved, conspicuous.

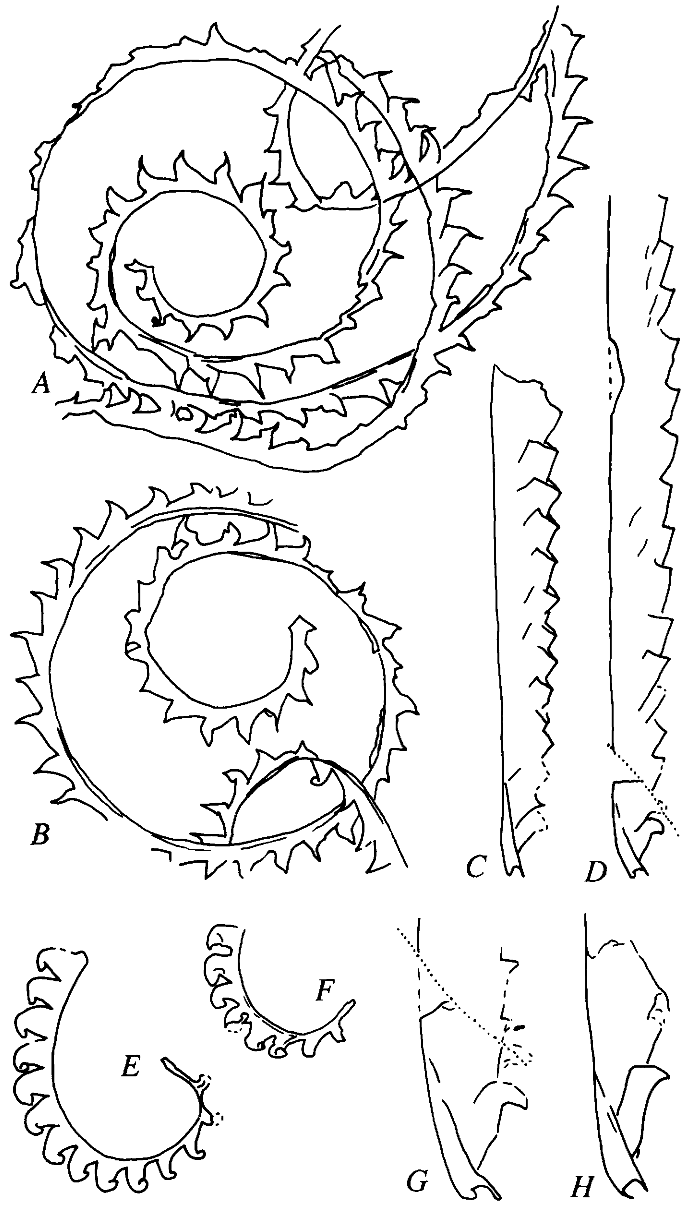


Figure 41. *Monograptus. A, B, M. delicatulus* Elles and Wood, USGS colln. 70ACn423, ×5: *A, B,* USNM 379175, part and counterpart. *C, D, G, H, M.* cf. *M. ludensis* (Murchison) sensu Wood: *C,* USNM 379177, USGS colln. 69ACn423, ×5; *D, G,* USNM 379178, USGS colln. 70ACn652, ×5 and ×10, respectively; *H,* USNM 379179, USGS colln. 70ACn552, ×10. *E, F, M.* cf. *M. millepeda* (McCoy), ×5: *E,* USNM 379198, USGS colln. 70ACn423; *F,* USNM 379199, USGS colln. 70ACn412. Dotted line indicates break in rock surface; dashed line is extrapolation of missing part of rhabdosome.

Monograptus digitatus digitatus n. subsp.

Figures 42*A–F*, *H–P*

Description.—The rhabdosome is broadly arcuate, with thecae on the convex side and a curved sicula that gives the appearance of ventral curvature at the extreme proximal end. It is as much as 3.5 cm long, 0.8 to 1.0 mm wide (averaging 0.9 mm) at th1 (see fig. 42*G*), increasing to a maximum width of 1.3 to 1.6 mm (average 1.4 mm) at the level of th4–9, and decreasing distally to a width of 1.1 to 1.5 mm (average 1.3 mm). The sicula is conspicuously curved toward the ventral margin of the rhabdosome and measures 1.4 to 2.3 mm long (average 1.8 mm). Its apex usually reaches part way along the length of the protheca of th2, and th1 arises 0.8 to 1.5 mm (average 1.1 mm) down from the apex.

The first 5 to 8 (average 6) thecae are rastritiform (tubular, isolate) with unmodified apertures. Distally, the thecae become overlapping, generally straight tubes of the pristiograptid type. Th1 is 1.0 to 1.2 mm long, th5 is 1.3 to 1.8 mm long (average 1.6 mm), and the distal thecae are 1.8 to

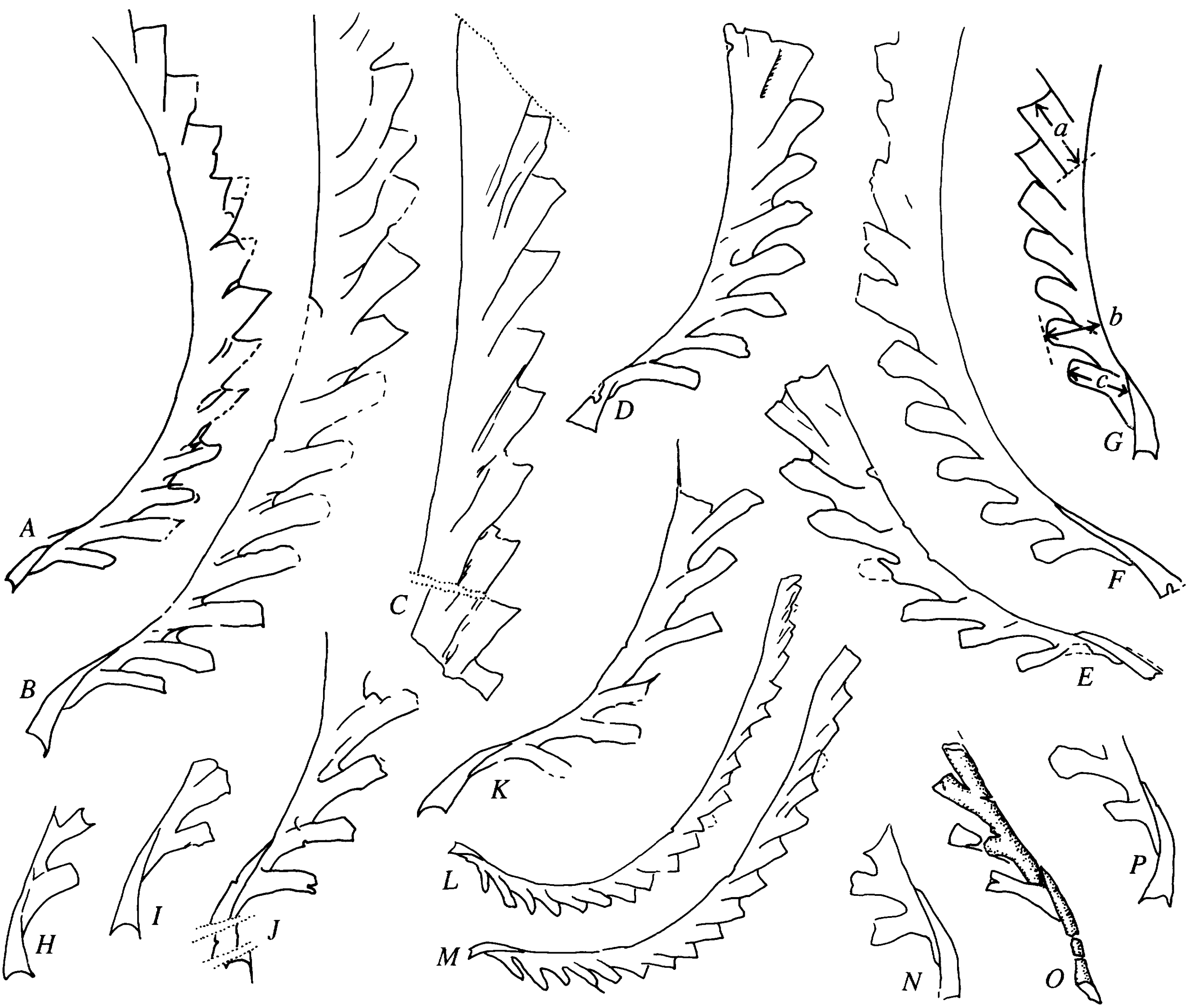


Figure 42. *Monograptus digitatus digitatus* n. sp. and n. subsp. ***A***, ***L***, USNM 379180, USGS colln. 70ACn91, ×10 and ×5, respectively; ***B***, USNM 379181, USGS colln. 70ACn91, ×10; ***C***, USNM 379182, USGS colln. 70ACn91, ×10; ***D***, USNM 379183, USGS colln. 70ACn91, ×10; ***E***, USNM 379184, USGS colln. 70AR8a, ×10; ***F***, USNM 379185, USGS colln. 70AR8a, ×10; ***G***, diagram showing measured dimensions (*a* = distal thecal length, *b* = width of rhabdosome, *c* = length of th1); ***H***, USNM 379186, USGS colln. 70AR8a, ×10; ***I***, USNM 379187, USGS colln. 70ACn91, ×10; ***J***, USNM 379188, USGS colln. 70ACn91, ×10; ***K***, USNM 379189, USGS colln. 70ACn91, ×10; ***M***, USNM 379190, USGS colln. 70AR7a, ×5; ***N***, USNM 379191b, USGS colln. 70AR8a, ×10; ***O***, USNM 379192, USGS colln. 70ACn91, ×10; ***P***, USNM 379191a, USGS colln. 70AR8a, ×10. Dotted line indicates break in rock surface; dashed line is extrapolation of missing part of rhabdosome.

2.2 mm long and overlap one-half to three-fifths of their length. The "Two-Thecae Repeat Distance" (2TRD) (Howe, 1983) for th2 is 1.4 to 1.8 mm (average 1.6 mm); it is 1.6 to 1.8 mm (average 1.6 mm) for th6 and 1.7 to 2.0 mm (average 1.8 mm) for th10.

Discussion.—This form is distinguished from all other species of *Monograptus* by its five to eight rastritiform proximal thecae along with its pristiograptid distal thecae, its curved rhabdosome, and its prominent curved sicula.

Occurrences.—Collections 69ACn431, 70ACn91, 70ACn111, 70AR7a, and 70AR8a; *M. digitatus* Zone.

Monograptus digitatus subdigitatus n. subsp.

Figures 43*A–F*

Description.—Associated with *M. digitatus digitatus* is a very similar form that differs only in being narrower and straighter and having fewer isolated thecae. The rhabdosome is nearly straight distally, slightly dorsally curved proximally, and has a ventrally curved sicula. It is as much as 2 cm long, 0.7 to 0.95 mm (average 0.8 mm) wide at th1, and attains a maximum width of 0.9 to 1.0 mm at th3–5, which is thereafter maintained. The conspicuously curved sicula is 1.7 to 2.3 mm long (average 2.0 mm) and th1 arises 1.2 to 1.3 mm down from its apex. The first one or two thecae (usually only one) are rastritiform, while the rest of the thecae are of the pristiograptid type. Th1 is 0.8 to 1.2 mm long (average 0.9 mm), th5 is 0.9 to 2.1 mm long (average 1.6 mm), and the distal thecae are 1.1 to 2.2 mm long (average 1.8 mm) and overlap about one-half their length. The 2TRD is 1.2 to 2.0 mm (average 1.6 mm) for th2, 1.4 to 2.2 mm (average 1.95 mm) for th6, and 2.1 mm for th10.

Discussion.—*M. d. subdigitatus* differs from *M. d. digitatus* in having a narrower, straighter rhabdosome and fewer isolated thecae. From all other species of *Monograptus* it is distinguished by its curved sicula and rastritiform proximal theca(e).

Occurrences.—Collections 69ACn431, 70ACn91, 70AR7a, and 70AR8a; *M. digitatus* Zone.

Monograptus cf. *M. ludensis* (Murchison) sensu Wood, 1900

Figures 41*C, D, G, H*

cf. *Monograptus ludensis* (Murchison, 1839), sensu Wood, 1900. Holland and others, 1969, p. 673–676, pl. 130, fig. 2, text-figs. 2a–j, 3a–e. Palmer, 1970, p. 338–340, pl. 14A–G, pl. 15A, B.

Description.—The rhabdosome is as much as 24 mm long, is 1.0 to 1.2 mm wide at the aperture of th1, and attains a maximum width of 1.6 to 1.8 mm. It is straight distally and exhibits varying degrees of ventral curvature in the proximal 2 mm of its length. The sicula is 1.5 to 2.2 mm long (usually about 2 mm) and ventrally curved. Th1, and sometimes th2, appears to have a rounded apertural region as in *M. ludensis*. The rest of the thecae are of the pristiograptid type, numbering 12 to 13 per centimeter proximally and 8 to 10 per centimeter distally.

Discussion.—The Terra Cotta Mountains specimens appear to have the same general dimensions, the ventrally curved sicula, and the rounded first thecal aperture characteristic of *M. ludensis*. However, they are not well preserved, and their distal thecae seem to be shorter and less overlapping than those of *M. ludensis.*

Occurrences.—Collections 69ACn423, 70ACn552, and 70ACn652; approximately *M. ludensis* Zone. *M. ludensis* occurs in the *M. ludensis* and *Neodiversograptus nilssoni* Zones in the British Isles (Holland and others, 1969; Palmer, 1970; Rickards, 1976).

Monograptus cf. *M. millepeda* (McCoy)

Figures 41*E, F*

cf. *Graptolites millepeda* McCoy, 1850, p, 270.

cf. *Monograptus millepeda* (McCoy). Elles and Wood, 1901–1918, p. 465–466, pl. 46, figs. 10a–d, text figs. 323*a–c*. Hutt, 1975, p. 96–97, pl. 22, figs. 1, 5; text-fig. 19, fig. 4.

Monograptus cf. *millepeda* (McCoy). Lenz, 1982, fig. 25G.

Description.—The hook-shaped rhabdosome is approximately 1 cm long and widens from 0.5 mm at th1, through 0.8 to 0.9 mm wide at th5, to a maximum of 1.1 mm. The thecae are triangular in outline, and their apertural portions coil into a prominent hook; they are spaced 12 to 14 per centimeter distally. The sicula appears to be about 0.8 mm long.

Discussion.—The Alaskan specimens appear to be identical with Lenz's (1982, fig. 25G) *M.* cf. *millepeda*, which also occurs in the *M. turriculatus* Zone. They differ from *M. millepeda* sensu stricto in being somewhat narrower and having a less robust proximal portion (their first three or four thecae seem to be smaller and more isolate).

Occurrences.—Collections 70ACn412 and 70ACn423; *M. turriculatus* Zone. *M. millepeda* occurs in the *M. argenteus* Zone (Road River Formation) of the Yukon Territory, Canada (Lenz, 1982), and the *M. argenteus* Zone in the British Isles (Hutt, 1975, Rickards, 1976).

Monograptus noyesensis Churkin and Carter

Figures 44*B–D, H, K*

Monograptus noyesensis Churkin and Carter, 1970, p. 42–43, pl. 4, figs. 9, 10, text figs. 17*A–C*.

Diagnosis.—Rhabdosome broadly arcuate with moderately curved proximal region; as much as 2 cm or more in length, widening gradually from 0.4 to 0.5 mm at aperture of th1 to maximum width of 1.0 to 1.3 mm. Thecae on convex margin, spaced 12 to 8 per centimeter, triangular in profile; proximal region of theca coiled into prominent hook. Sicula 1.0 to 1.2 mm long.

Discussion.—The proximal thecae are somewhat elongated, while distally the thecae become bluntly triangular and resemble those of *M. millepeda. M. noyesensis* may be distinguished from species with similar thecae such as *M. millepeda* and *M. pseudoplanus* Sudbury by the characters of its proximal end—the gentle curvature and the moderately elongated first 5 or 6 thecae that are larger than those of *M. pseudoplanus* and more numerous than those of *M. millepeda.*

Figure 43. *Monograptus digitatus subdigitatus* n. sp. and n. subsp. ***A***, USNM 379194, USGS colln. 70AR8a, ×10; ***B, D***, USNM 379195, USGS colln. 70AR8a, ×10 and ×5, respectively; ***C, E***, USNM 379196, USGS colln. 70AR8a, ×5 and ×10, respectively; ***F***, USNM 379197, USGS colln. 70ACn91, ×10.

Occurrences.—Collection 69ACn363; *M. convolutus* Zone. *M. gregarius* Zone (Descon Formation) in southeastern Alaska (Churkin and Carter, 1970).

Monograptus runcinatus runcinatus Lapworth

Figures 44*E–G*

Monograptus runcinatus Lapworth, 1876a, p. 501–502, pl. 20, figs. 4*a–g*. Lapworth, 1876b, pl. 1, fig. 26. Törnquist, 1892, p. 27–28, pl. 2, figs. 29, 30. Elles and Wood, 1901–1918, p. 450–451 (in part), pl. 45, figs. 2c–g (not figs. 2a, b), text figs. 309*e,f* (not text figs. 309*a–d*).

Diversograptus runcinatus (Lapworth). Strachan, 1952, p. 365–368, text-figs. 1*a–c*. Bjerreskov, 1975, p. 90, text fig. 27A, pl. 13, fig. D.

not *Monograptus* (*Streptograptus*) *runcinatus* (Lapworth). Bouček and Přibyl, 1942, p. 11–12, figs. 5a–d, pl. 2, figs. 1–3.

?*Diversograptus* (*Paradiversograptus*) *runcinatus* (Lapworth). Sennikov, 1976, p. 228–230, pl. 17, figs. 7, 8.

Diagnosis.—Rhabdosome slender, straight or slightly curved, several centimeters long, widening gradually from 0.25 mm at th1 to maximum width of 0.9 mm distally. Thecae have free ventral walls parallel to axis of rhabdosome and reflexed apertural portions, spaced 12 per centimeter proximally to 8 1/2 per centimeter distally. Reflexed parts of thecae occupy one-third of stipe width. Sicula 1.2 mm long, its apex reaches base of th2. Sicular cladia present in some rhabdosomes (diversograptid development).

Discussion.— The Terra Cotta Mountains specimens are as much as 2.5 cm long and 0.3 to 0.6 mm wide, with 8 to 10 thecae per centimeter and siculae 1.3 mm long. They are not well preserved but appear to have the rather sagging metathecal profile characteristic of *M. r. runcinatus.* Two specimens possess sicular cladia as described and illustrated by Strachan (1952) and Bjerreskov (1975, p. 90, text fig. 27A). However, because the development of a bipolar siculate rhabdosome is not limited to the genus *Diversograptus* (see Rickards, 1973, p. 183), *runcinatus* is here retained in the genus *Monograptus*, following the reasoning of Hutt (1975, p. 106).

M. runcinatus runcinatus is distinguished from *M. runcinatus richardsonensis* Lenz by its much less strongly recurved proximal portion and its greater maximum width. It is distinguished from other species by the characteristic sagging or somewhat melted profile of the retroverted metathecal portions in flattened specimens.

Occurrences.— Collections 70ACn202 and 70ACn412; *M. turriculatus* Zone. *Rastrites maximus* and *M. turriculatus* Zones (Birkhill Shale) in Scotland (Elles and Wood, 1901–1918; Rickards, 1976). *M. turriculatus* Zone (Road River Formation) in the northern Yukon Territory, Canada (Lenz, 1982). *M. turriculatus* Zone on Bornholm Island, Denmark (Bjerreskov, 1975).

Monograptus sartorius Törnquist

Figures 44*L–N*

Monograptus sartorius Törnquist, 1881, p. 441, pl. 17, fig. 6a–c. Törnquist, 1892, p. 23, pl. 2, figs. 12–15. Howe, 1982, pl. 2, fig. i.

Monograptus (*Globosograptus*) *sartorius* Törnquist. Bouček and Přibyl, 1951, p. 189–190, pl. 2, figs. 8–9, text fig. 1a.

Monograptus cf. *sartorius* Törnquist. Lenz, 1982, p. 105–106, figs. 9A–C, 29D, H.

Diagnosis.—Rhabdosome slender (0.3 to 0.4 mm wide), dorsally curved initially, nearly straight distally. Thecae with long slender prothecal portions and metathecal portions coiled into lobes, spaced 8 to 9 per centimeter.

Discussion.—*M. sartorius* is distinguished from similar species by the proximal gentle dorsal curvature, the extreme narrowness of its rhabdosome, and the spacing of its thecae.

M. cf. *sartorius*, described by Lenz (1982) from the *M. turriculatus* and *M. spiralis* Zones of the Road River Formation of the northern Yukon Territory, is very close to the Alaskan specimens in rhabdosome size and shape, but its metathecae are reportedly short sharp hooks.

Occurrences.— Collections 70ACn202, 70ACn412, and 70ACn423; *M. turriculatus* Zone. Silurian strata in Sweden (Törnquist, 1881; 1892). *M. griestoniensis* Zone (EK Formation) in Norway (Howe, 1982). *M. griestoniensis* through *M. spiralis* Zones in Bohemia (Bouček and Přibyl, 1951).

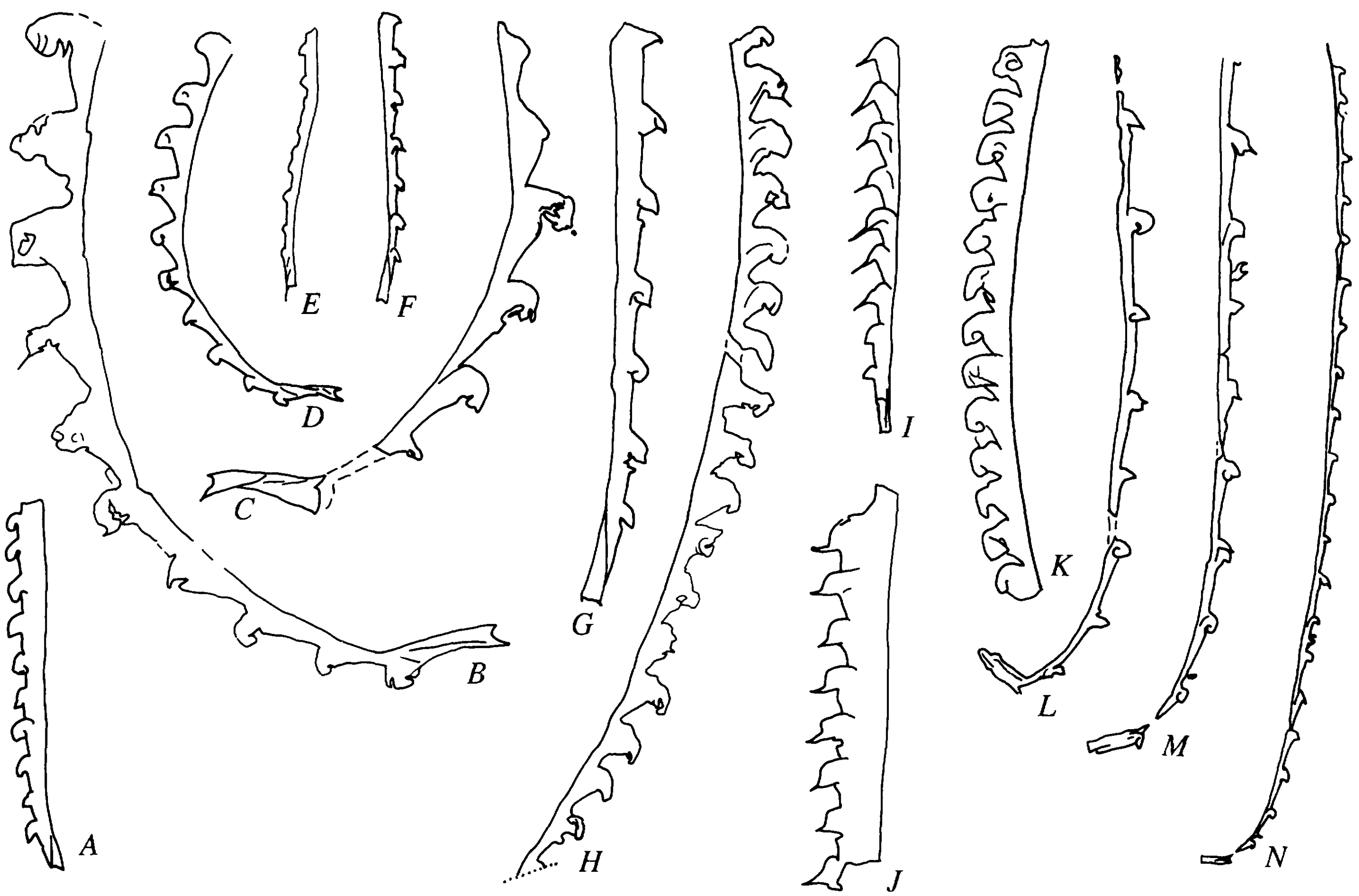


Figure 44. *Monograptus*. ***A, I, J***, *M. sedgwickii* (Portlock), all from USGS colln. 70ACn423, all ×5: ***A***, USNM 379208; ***I***, USNM 379209; ***J***, USNM 379210. ***B–D, H, K***, *M. noyesensis* Churkin and Carter, all from USGS colln. 69ACn363: ***B, D***, USNM 379200, ×10 and ×5, respectively; ***C***, USNM 379201, ×10; ***H***, USNM 379202, ×5; ***K***, USNM 379203, ×5. ***E–G***, *M. runcinatus runcinatus* Lapworth: ***E***, USNM 379204, USGS colln. 70ACn412, ×5; ***F, G***, USNM 379205, USGS colln. 70ACn202, ×5 and ×10, respectively. ***L–N***, *M. sartorius* Törnquist: ***L***, USNM 379206, USGS colln. 70ACn202, ×10; ***M, N***, USNM 379207, USGS colln. 70ACn412, ×10 and ×5, respectively. Dashed line is extrapolation of missing part of rhabdosome.

Monograptus sedgwickii (Portlock)

Figures 44*A*, *I*, *J*

Graptolithus (Prionotus) Sedgewickii Portlock, 1843, p. 318, pl. 19, fig. 1.
Monograptus Sedgwickii (Portlock). Elles and Wood, 1901–1918, p. 441–443, pl. 44, figs. 10a–f, text figs. 304*a–e*.
Monograptus sedgwicki (Portlock). Obut and others, 1967, p. 97–98, pl. 11, figs. 3, 4. Lenz, 1982, p. 106–109, figs. 9D, E; 29E–G.
Monograptus sedgwickii (Portlock). Rickards, 1970, p. 73–74, text-fig. 14, fig. 34. Golikov, 1973, p. 35–36, pl. 6, fig. 9?. Cocks and Toghill, 1973, pl. 1, fig. 8. Hutt, 1975, p. 106, pl. 24, fig. 1, text-fig. 24, figs. 11–14. Koren' and Markova, 1976, p. 92–93, pl. 2, fig. 6?, pl. 6, figs. 4, 5?, 6–8, 9?. Carter and Churkin, 1977, p. 30, pl. 5, fig. 4.

Diagnosis.—Rhabdosome straight or slightly flexed, 20 cm or more in length, widening gradually from 0.5 to 0.7 mm across th1 to maximum width of 2 to 3 mm (excluding apertural spines). Sicula about 1.5 mm long. Thecae number 10 to 11 per centimeter proximally, 6 to 9 per centimeter distally; isolated and retroverted apertural portions occupy about half the rhabdosome width. Apertural margin usually spined.

Discussion.—The Alaskan specimens agree well with the above description. *M. sedgwickii* is distinguished from similar forms such as *M. halli* (Barrande) and *M. rickardsi* Hutt by its dorsally curved proximal end and the details of its sicula and thecae.

Occurrences.—Collection 70ACn423; *M. sedgwickii* Zone. *M. convolutus* Zone (Phi Kappa Formation) in Idaho (Carter and Churkin, 1977). *M. sedgwickii* and lower *M. turriculatus* Zones (Road River Formation) in the northern Yukon Territory, Canada (Lenz, 1982). *M. convolutus* and *M. sedgwickii* Zones in the British Isles (Elles and Wood, 1901–1918; Rickards, 1970, 1976; Cocks and Toghill, 1973; Hutt, 1975). *Demirastrites convolutus* and *M. sedgwickii* Zones in Kolyma River area, eastern Siberia (Obut and others, 1967) and in south-central part of the former USSR (Golikov, 1973). Also reported from Mongolia (Koren' and Markova, 1976).

Monograptus sidjachenkoi (Obut and Sobolevskaya)

Figures 45*B*, *C*, *F*, *G*

Pernerograptus sidiachenkoi Obut and Sobolevskaya, in Obut and others, 1965, p. 61, pl. 9, figs. 2–4.
Pernerograptus sidjachenkoi Obut and Sobolevskaya. Obut and others, 1967, p. 111–112, pl. 15, figs. 2–7.
?*Paramonoclimacis similis* Wang and Ma, in Wang and Jin, 1977, p. 361, pl. 111, fig. 5.
?*Paramonoclimacis typicalis* Wang and Ma, in Wang and Jin, 1977, p. 362, pl. 111, figs. 2, 3, text fig. 47.
Monograptus sidjachenkoi (Obut and Sobolevskaya). Lenz, 1982, p. 109–110, figs. 8N, P, R, 27B, E, F.

Diagnosis.—Rhabdosome 2 to 3 cm long; proximal portion tightly to moderately tightly coiled through 270° to 400°, distal portion weakly curved or straight. Initial width (at sicula) 0.1 to 0.2 mm; width increases within first 10 mm to 1.0 to 1.5 mm, which is thereafter maintained. First 9 to 11 thecae have lobed apertural portions and ventral walls parallel to stipe axis. Distally, thecal apertures become hooded excavations. Thecae number 12 to 8 per centimeter. Sicula approximately 1 mm long.

Discussion.—The Terra Cotta Mountains specimens match the above diagnosis quite well. They are as long as 3 cm, increase in width from 0.25 mm at th1 to a maximum of 1.2 to 1.3 mm, and have 12 to 9 thecae per centimeter. They are very closely similar to specimens of *M. sidjachenkoi* from southeastern Alaska (Carter, unpub. data, 1983) and from the northern Yukon Territory (Lenz, 1982), except that the Canadian specimens have wider proximal ends (0.5 to 0.6 mm wide at th1).

Occurrences.—Collection 70ACn281; *M. convolutus* Zone. *M. convolutus* Zone (Descon Formation) in southeastern Alaska (Carter, unpub. data, 1983). *M. convolutus* Zone (Road River Formation) in the northern Yukon, Canada (Lenz, 1982). *Demirastrites convolutus* Zone in central Taimyr (Obut and others, 1965) and Kolyma River region in the former USSR (Obut and others, 1967). South-central China? (Wang and Jin, 1977).

Monograptus turriculatus (Barrande)

Figures 45*E*, *I*

Graptolithus turriculatus Barrande, 1850, p. 56–57, pl. 4, figs. 7–11.
Graptolites turriculatus Barrande. Nicholson, 1868, p. 542, pl. 20, figs. 29, 30.
Monograptus turriculatus (Barrande). Lapworth, 1876a, p. 359–360, pl. 13, fig. 6*a*. Lapworth, 1876b, pl. 1, fig. 23. Linnarsson, 1881, p. 518–520, pl. 22, figs. 13–18. Törnquist, 1892, p. 38–39, pl. 3, figs. 24–26. Elles and Wood, 1901–1918, p. 438–439, pl. 44, figs. 4a–e, text figs. 301*a–c*. Sherwin, 1974, p. 172, pl. 12, fig. 6. Hutt, 1975, p. 111–112, text-fig. 22, figs. 9, 10. Bjerreskov, 1975, p. 70–71, pl. 10, fig. 4. Lenz, 1982, p. 118–121, figs. 9N, 32D, E, G, 33A–C. Howe, 1982, pl. 2, fig. f.
Spirograptus turriculatus (Barrande). Obut and others, 1967, p. 115–116, pl. 16, fig. 4. Teller and Korejwo, 1968, pl. 3, figs. 1, 2, 5. Koren' and Enokyan, 1970, pl. 2, figs. 3–5. Sennikov, 1976, p.192–194, pl. 13, figs. 2–4. Wang and Jin, 1977, p. 363, pl. 110, fig. 8. Wang, 1978, p. 311, pl. 3, fig. 6.
Spirograptus minor (Bouček). Obut and others, 1967, p. 116–117, pl. 16, fig. 5. Koren' and Enokyan, 1970, pl. 2, figs. 1, 2. Sennikov, 1976, p. 194–196, pl. 13, figs. 5–7. Wang and Jin, 1977, p. 363, pl. 110, figs. 9, 10. Wang, 1978, p. 311–112, pl. 1, fig. 7.
Spirograptus turriculatus minor (Bouček). Teller and Korejwo, 1968, pl. 3, fig. 6.

Diagnosis.—Rhabdosome coiled into conical spiral of as many as eight whorls, widening gradually from 0.5 mm at th1 to maximum of 3 mm (excluding spines) in largest specimens. Sicula curved, 1.0 to 1.2 mm long. Thecae triangular, with small apertural hooks and long apertural spines, spaced 16 to 12 per centimeter.

Discussion.—None of the many Terra Cotta Mountains specimens of this species are as large as the larger specimens illustrated by Lenz (1982, figs. 32G, 33A, B). However, they all display the conical spiral and spined thecae that distinguish *M. turriculatus* from all other species.

Occurrences.—Collections 70ACn152, 70ACn202, 70ACn412, 70ACn423, and 70ACn621; *M. turriculatus* Zone. *M. turriculatus* Zone in the Yukon Territory, Canada (Lenz, 1982). *Rastrites maximus* through *M. crispus* Zones in the British Isles (Elles and Wood, 1901–1918; Hutt, 1975; Rickards, 1976). *M. turriculatus* Zone on Bornholm Island, Denmark (Bjerreskov, 1975). Also found in Norway (Howe, 1982), the former USSR (Obut and others, 1967; Koren' and Enokyan, 1970; Sennikov, 1976), Poland (Teller and Korejwo, 1968), New South Wales, Australia (Sherwin, 1974), and China (Wang and Jin, 1977; Wang, 1978).

Monograptus cf. *M. uncinatus micropoma* (Jaekel) sensu Elles and Wood

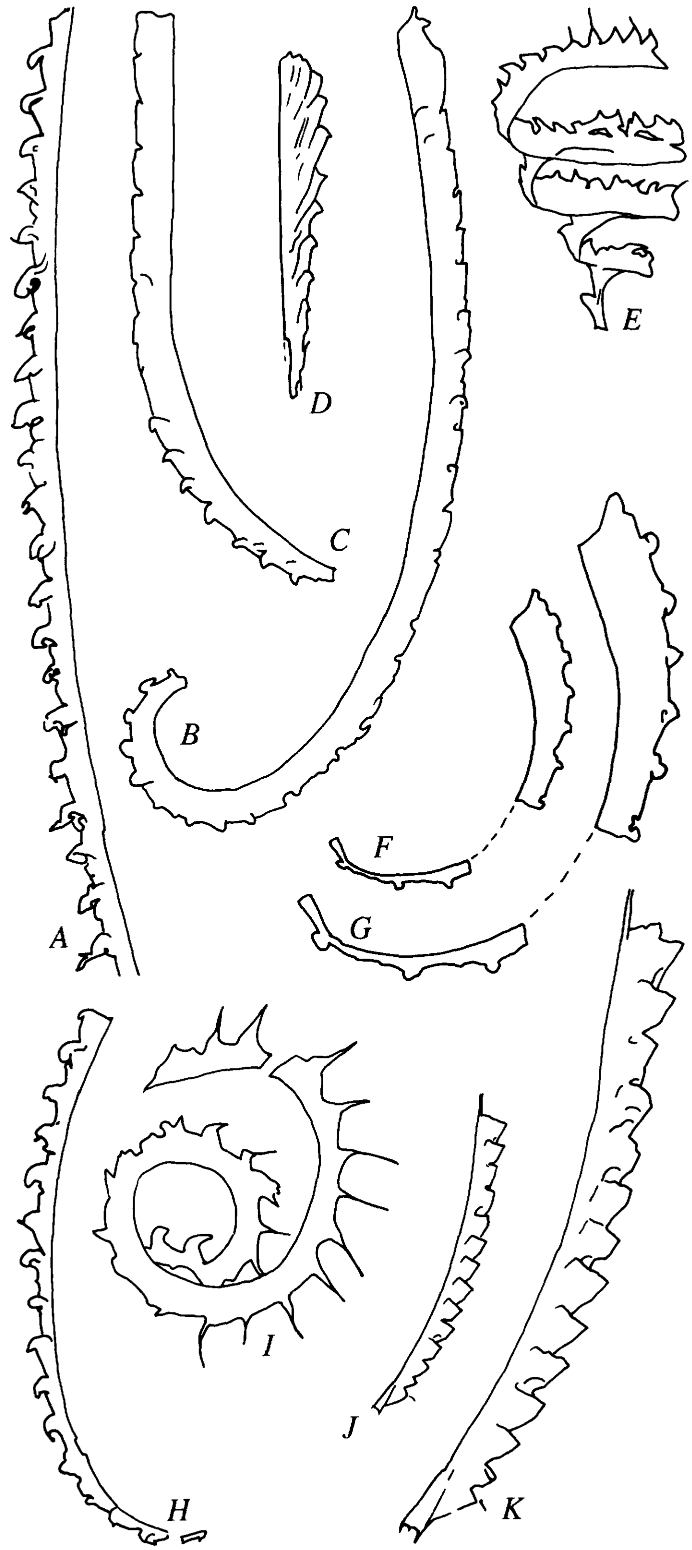
Figure 45*D*

cf. *Monograptus uncinatus* var. *micropoma* (Jaekel). Wood, 1900, p. 477–479, pl. 25, figs. 24A, B; text figs. 21*a*, *b*. Elles and Wood, 1901–1918, p. 428–429, pl. 43, figs. 2a–c; text figs. 291*a*, *b*.

Description.—The single, incomplete rhabdosome is 9 mm long and attains a maximum width of 1.3 mm near its distal end. The proximal end is damaged, and the sicula is not discernible. The thecae number about 5½ in 5 mm, and they increase in length and amount of overlap toward the distal end of the rhabdosome. Their apertural regions are rounded into slight hooks.

Discussion.—The Terra Cotta Mountains specimen matches the British form in dimensions, but its apertural regions are less conspicuously beak-like, possibly due to poor preservation.

Occurrences.—Collection 70AR8a; *M. digitatus* Zone. *M. uncinatus micropoma* occurs in the *Neodiversograptus nilssoni* and *Lobograptus scanicus* Zones (lower Ludlow Shales) in the British Isles (Wood, 1900; Elles and Wood, 1901–1918).



► **Figure 45.** *Monograptus*. ***A***, ***H***, *M. undulatus* Elles and Wood, USGS colln. 69ACn363, ×5: ***A***, USNM 379217; ***H***, USNM 379218. ***B***, ***C***, ***F***, ***G***, *M. sidjachenkoi* (Obut and Sobolevskaya), all from USGS colln. 70ACn281: ***B***, USNM 379211, ×5; ***C***, USNM 379212, ×5; ***F***, ***G***, USNM 379213, ×5 and ×8, respectively. ***D***, *M.* cf. *M. uncinatus micropoma* (Jaekel) sensu Elles and Wood, USNM 379216, USGS colln. 70AR8a, ×5. ***E***, ***I***, *M. turriculatus* (Barrande), USGS colln. 70ACn412: ***E***, USNM 379214, ×5; ***I***, USNM 379215, ×8. ***J***, ***K***, *M.* sp. A, USNM 379219, USGS colln. 70ACn412, ×5 and ×10, respectively. Dashed line is extrapolation of missing part of rhabdosome.

Monograptus undulatus Elles and Wood

Figures 45*A*, *H*

Monograptus undulatus Elles and Wood, 1901–1918, p. 432, pl. 45, fig. 5, text fig. 295. Rickards and others, 1977, fig. 26. Chen, 1983, p. 54, pl. 9, fig. 10.

Diagnosis.—Rhabdosome several centimeters long, slender, flexed, with conspicuously recurved proximal end; increases gradually in width to a maximum of 1 mm, which is maintained for most of its length. Thecae number 10 to 8 per centimeter, with prothecae slightly inclined to rhabdosome axis, metathecae curved into hooks, and apertural margins retroverted. Sicula 1.1 mm long.

Discussion.—*M. undulatus* may be distinguished from other species with hooked thecae by its relatively narrow rhabdosome. From *M. noyesensis*, with which it occurs in the Terra Cotta Mountains section, it differs in being narrower and having thecae less isolate and less triangular.

Occurrences.—Collection 69ACn363; *M. convolutus* Zone. *M. convolutus* Zone in the British Isles (Rickards, 1976). *Streptograptus exiguus* Zone in China (Chen, 1983). Lenz (1982, p. 121) reports *M.* cf. *M. undulatus* from the *M. sedgwickii* Zone of the northern Yukon Territory, Canada.

Monograptus sp. A

Figures 45*J*, *K*

Description.—The rhabdosome is very gently curved dorsally, 8.5 mm long; width is 0.6 mm at the aperture of th1, increasing to a maximum of 0.8 mm near th6. The thecae appear to be somewhat geniculate, in the manner of *Glyptograptus*, and they number 9 to 8 in 5 mm. The sicula extends above the aperture of th1 and measures about 1.0 mm in length.

Discussion.—The single Terra Cotta Mountains specimen resembles *M. norfordi* Lenz in general size and appearance but is a bit narrower and has more thecae per centimeter and a much shorter, straighter sicula; it lacks the beak-like proximal thecae of the much younger *M. norfordi.* It is distinguished by its nearly constant width, relatively broad proximal end, gently curved rhabdosome, and geniculate thecae.

Occurrence.—Collection 70ACn412; *M. turriculatus* Zone.

Monograptus sp. B

Figures 46*B–D*

Description.—The rhabdosome is irregularly coiled into little more than one whorl 5 to 10 mm in diameter. It increases gradually in width from 0.6 mm at the aperture of th1 to a maximum of 1.0 mm at about th10 or 11. The thecae are on the convex margin, spaced 10 to 11 per centimeter, with little or no overlap. Proximally, the first one or two metathecae are nearly rastritiform, with the apertural region coiled into a conspicuous hook. The metathecae gradually become more triangular toward the distal part of the rhabdosome, but the hooked apertural region is retained. The sicula is 1.0 mm long and extends approximately to the level of the first thecal aperture.

Discussion.—The Terra Cotta Mountains form resembles *M. delicatulus* Elles and Wood and *M. involutus* Lapworth in its irregularly coiled rhabdosome but differs from *M. delicatulus* in the shape of its thecae (the apertures of *M. delicatulus* are not coiled into hooks). It differs from *M. involutus* in having a more robust proximal portion. From other coiled forms it differs by being narrower and more irregularly coiled into only one small whorl.

Occurrence.—Collection 70ACn173; *Cyrtograptus centrifugus* Zone.

Genus *Monoclimacis* Frech, 1897

Monoclimacis cf. *M. crenulata* sensu Elles and Wood

Figures 46*A*, *E*, *F*, *I*

cf. *Monoclimacis vomerinus* var. *crenulatus* (Törnquist). Elles and Wood, 1901–1918, p. 412, pl. 41, figs. 4a–d, text figs. 278*a–e*.

cf. *Monoclimacis crenulata* sensu Elles and Wood. Rickards and others, 1977, pl. 6, fig. 4.

Description.—The rhabdosome is straight or slightly flexed, as long as 34 mm, and increases gradually in width from 0.5 to 0.6 mm at th1, through 0.8 mm at th10, to a maximum of 1.0 to 1.3 mm distally. The thecae are biform and number 9½ to 10 per centimeter proximally and 8 to 9 per centimeter distally. The first three to four thecae have hooked apertural regions while the rest of the thecae are geniculate, with nearly vertical supragenicular walls and apertures opening into shallow excavations. The sicula is 1.3 to 1.6 mm long and extends to the top of th1 or slightly beyond.

Discussion.—The Alaskan form compares well with *M. crenulata* sensu Elles and Wood, particularly the specimen figured by Rickards and others (1977, pl. 6, fig. 4), but differs in having a greater number of hooked thecae and slightly fewer thecae per centimeter.

Occurrences.—Collections 69ACn362, 70ACn34, and 70ACn35; *M. spiralis* Zone. *M. crenulata* sensu Elles and Wood occurs in the *M. crenulata* Zone in the British Isles (Rickards, 1976).

Monoclimacis sp. A

Figures 46*G*, *H*, *J–L*

Description.—The rhabdosome is as long as 14 mm, nearly straight with only slight dorsal curvature in the proximal part. It widens slowly from 0.6 to 0.7 mm across the aperture of th1, through 0.9 mm at th5, to a maximum of 1.5 mm (measured on a distal fragment). The thecae are spaced about 11 to 8 per centimeter, and they are biform. The proximal three thecae have hooked apertural regions while the distal thecae are geniculate with nearly vertical supragenicular walls and apertures opening into excavations that occupy about one-fourth to one-third the width of the rhabdosome. The sicula is 1.6 to 1.7 mm long, and its apex extends above the aperture of th1.

Discussion.—This form differs from the associated form *M.* cf. *M. crenulata* by being wider throughout its length and having a longer sicula. It compares well with the proximal portion of *M. vomerina basilica* (Lapworth) in dimensions and thecal spacing but differs in having a longer sicula. The sicula of *M. v. basilica* is only 1.25 to 1.5 mm long and extends to the level of the aperture of th1 (Bjerreskov, 1975, p. 57). In addition, the Terra Cotta Mountains specimens lack the prominent thecal hoods illustrated by Bjerreskov (1975, fig. 17D).

Occurrence.—Collection 69ACn362; *M. spiralis* Zone.

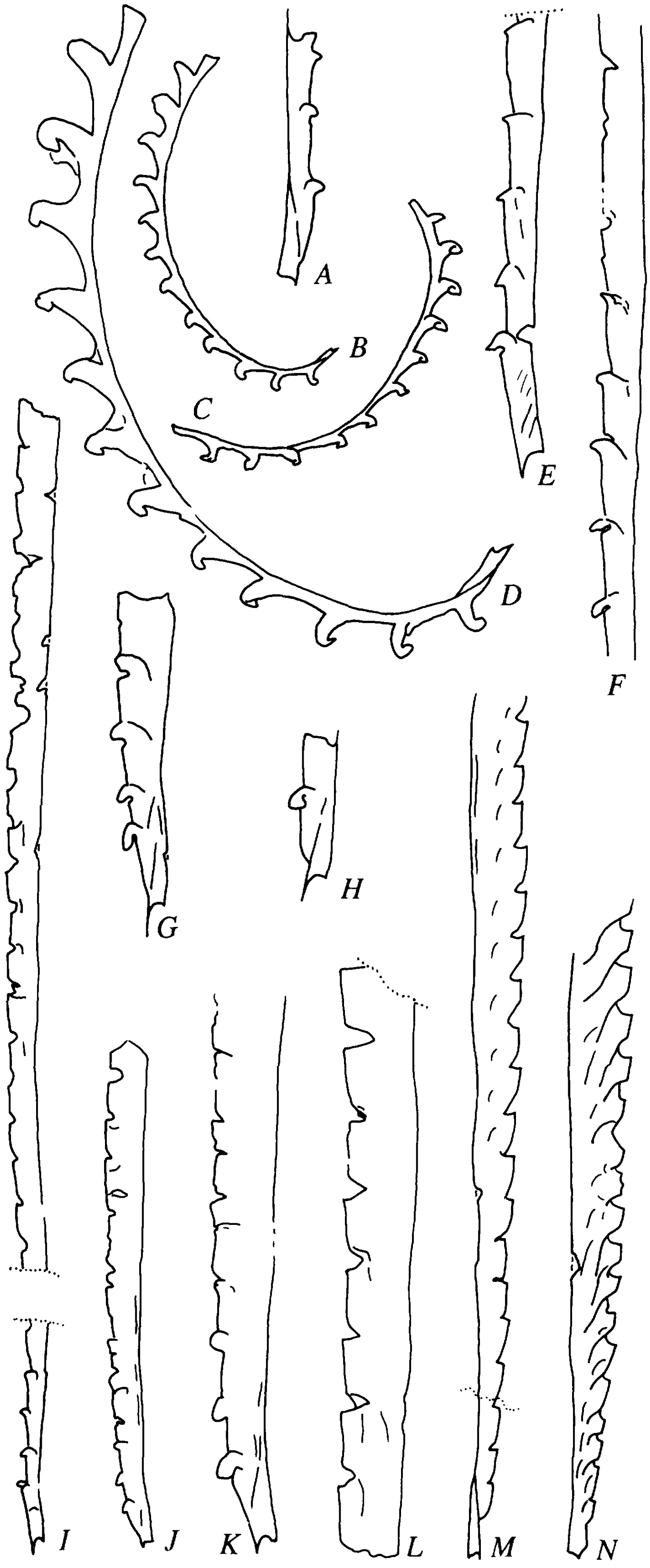
Monoclimacis sp. B

Figure 46*N*

Description.—The rhabdosome is nearly straight, is 19 mm long, and its width increases rapidly from 0.5 mm at th1, through 0.9 mm at th5 and 1.5 mm at th10, to 1.7 mm at th15. The thecae number 6 in 5 mm proximally and 9 per centimeter distally, and the thecal excavations occupy about one-fourth the width of the rhabdosome. The thecae are geniculate and appear to lack thecal hoods.

Discussion.—Both Terra Cotta Mountains specimens have such poorly preserved proximal ends that details of the sicula cannot be distinguished. The rhabdosome widens more rapidly than in any other species of *Monoclimacis*, and the thecae are more closely spaced proximally than in *M. v. vomerina* (Nicholson) or *M. v. basilica* (Lapworth).

Occurrence.—Collection 69ACn341; *Monograptus spiralis* Zone.



► **Figure 46.** *Monoclimacis* and *Monograptus*. ***A, E, F, I***, *Monoclimacis* cf. *M. crenulata* sensu Elles and Wood: ***A***, USNM 379222, USGS colln. 69ACn362, ×10; ***E, I***, USNM 379223, USGS colln. 69ACn362, ×10 and ×5, respectively; ***F***, USNM 379224, USGS colln. 70ACn34, ×10. ***B–D***, *Monograptus* sp. B, all from USGS colln. 70ACn173: ***B, D***, USNM 379220, ×5 and ×10, respectively; ***C***, USNM 379221, ×5. ***G, H, J–L***, *Monoclimacis* sp. A, all from USGS colln. 69ACn362: ***G***, USNM 379225, ×10; ***H***, USNM 379226, ×10; ***J, K***, USNM 379227, ×5 and ×10, respectively; ***L***, USNM 379228, ×10. ***M***, *Monoclimacis* sp. C, USNM 379230, USGS colln. 70ACn755, ×5. ***N***, *Monoclimacis* sp. B, USNM 379229, USGS colln. 69ACn341, ×5. Dotted line indicates break in rock surface.

Monoclimacis sp. C

Figure 46*M*

Description.—The nearly straight rhabdosome is 24 mm long and widens rapidly from 0.5 mm at th1, through 0.7 mm at th5 and 1.1 mm at th10, to a maximum of 1.5 mm at th16. The thecae number 9 per centimeter proximally and 8 1/2 per centimeter distally. They are geniculate, with apertures opening into relatively shallow excavations, and lack any evidence of thecal hoods. The sicula is 2.2 mm long, with its apex slightly above the aperture of th1; half the length of its ventral margin is free.

Discussion.—The single specimen somewhat resembles *M. f. flumendosae* Gortani but is straight and widens more rapidly than that species. It widens at about the same rate as *M. v. vomerina* but has fewer thecae per centimeter.

Occurrence.—Collection 70ACn755; *Cyrtograptus lundgreni* Zone.

Genus *Pristiograptus* Jaekel, 1889
Pristiograptus dubius dubius (Suess)

Figure 47*F*

Graptolithus dubius Suess, 1851, p. 115, pl. 9, figs. 5*a*, *b*.
Monograptus colonus var. *dubius* Suess. Lapworth, 1876a, p. 506, pl. 20, figs. 10*e*–*g*.
Monograptus dubius (Suess). Holm, 1890, p. 16–17, pl. 1, figs. 18–26. Wood, 1900, p. 454–455, pl. 25, figs. 1A, B; text fig. 9. Elles and Wood, 1901–1918, p. 376–378, pl. 37, figs. 7a–d, text figs. 247*a*, *b*. Walker, 1953, p. 365–370, text-figs. 2, 3. Jaeger, 1975, pl. 2, fig. 3, text figs. 5a, b.

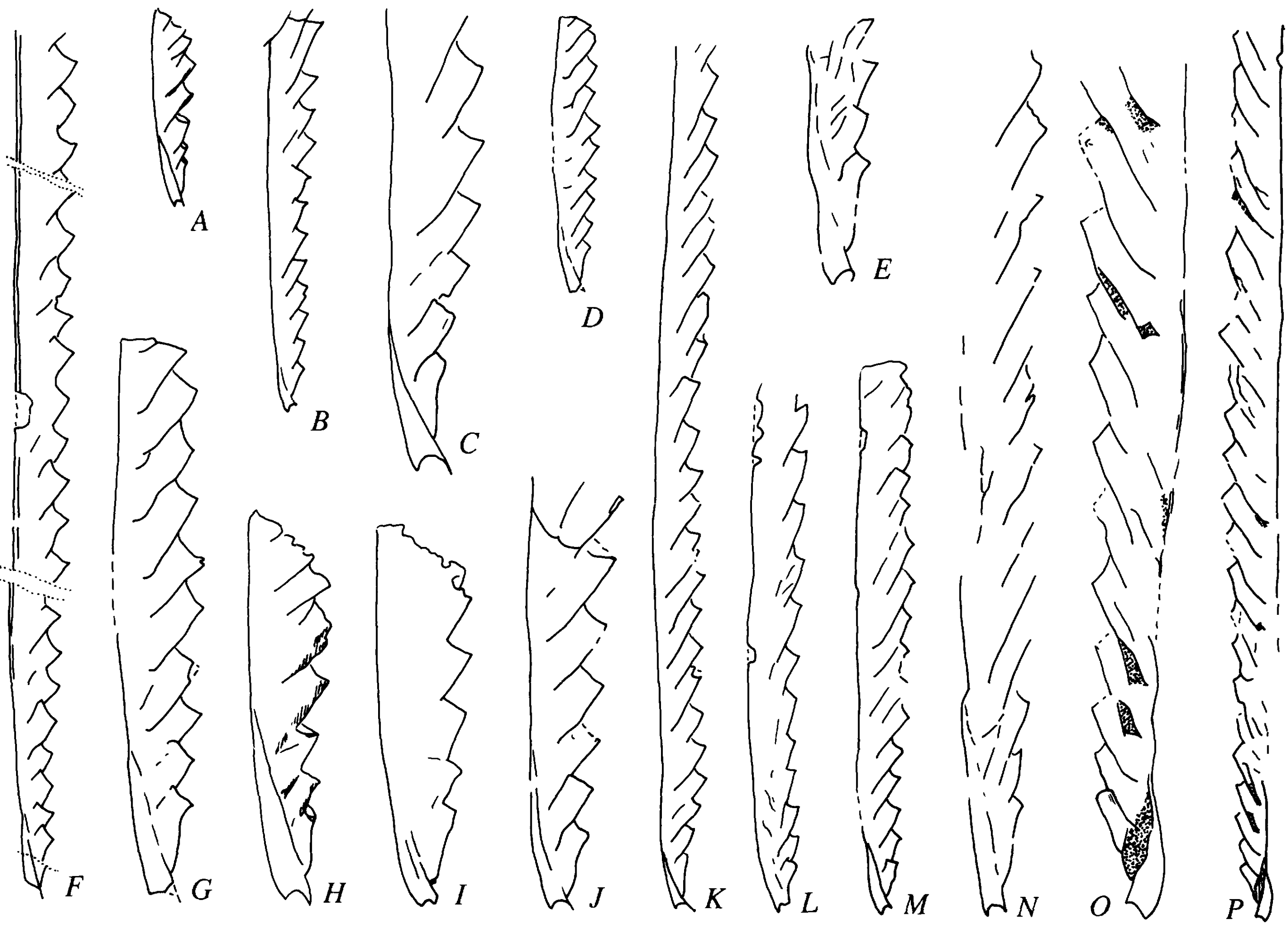


Figure 47. *Pristiograptus*. ***A–D***, ***G–M***, *P.* aff. *P. dubius* (Suess): ***A***, ***H***, USNM 379232, USGS colln. 69ACn423, ×5 and ×10, respectively; ***B***, USNM 379233, USGS colln. 70AR6g, ×5; ***C***, ***K***, USNM 379234, USGS colln. 70AR6g, ×10 and ×5, respectively; ***D***, ***G***, USNM 379235, USGS colln. 69ACn423, ×5 and ×10, respectively; ***I***, USNM 379236, USGS colln. 70ACn552, ×10; ***J***, USNM 379237, USGS colln. 70AR6g, ×10; ***L***, USNM 379238, USGS colln. 70ACn652, ×5; ***M***, USNM 379239, USGS colln. 70AR6g, ×5. ***E***, ***N–P***, *P.* cf. *P. jaegeri* Holland, Rickards, and Warren, all from USGS colln. 70AR6b: ***E***, USNM 379240, ×10; ***N***, USNM 379241, ×10; ***O***, ***P***, USNM 379242, ×10 and ×5, respectively. ***F***, *P. dubius dubius* (Suess), USNM 379231, USGS colln. 70ACn755, ×5. Dotted line indicates break in rock surface; dashed line is extrapolation of missing part of rhabdosome.

Pristiograptus dubius (Suess). Holland and others, 1969, pl. 130, fig. 7. Cocks and Rickards, 1969, pl. 10, fig. *a*.

Diagnosis.—Rhabdosome long; straight except for slight ventral curvature over first 5 to 6 thecae. Width increases gradually from 0.7 to 0.8 mm at th1 to maximum of 2 mm. Sicula 1.8 mm long, with apex just below aperture of th2. Thecae pristiograptid, inclined to rhabdosome axis at 30° to 35°, overlapping approximately half their length, numbering 10 to 11 per centimeter proximally and 8 per centimeter distally.

Discussion.—The Terra Cotta Mountains specimen agrees almost perfectly with the British form described by Wood (1900).

Occurrences.—Collection 70ACn755; *Cyrtograptus ludgreni* Zone. Zones of *Monograptus riccartonensis* through *M. ludensis* in the British Isles (Rickards, 1976). *P. dubius* has also been reported from Sweden (Holm, 1890), the Carnic Alps (Jaeger, 1975), and, less reliably, from other areas in Europe, the former USSR, and Australia.

Pristiograptus aff. P. dubius (Suess)

Figures 47*A–D*, *G–M*

Description.—The rhabdosome is as much as 27 mm long (usually shorter) and widens from 0.8 mm at the aperture of th1, through 1.1 to 1.3 mm wide at th5, to a maximum of 1.4 to 1.6 mm distally. It is straight in the dorsal part, while the proximal 3 to 5 mm exhibit slight ventral curvature. Some rhabdosomes (figs. 47*C*, *K*) also have slight dorsal curvature over th3 to th6. The thecae are pristiograptid and number 6 to 7 in 5 mm proximally and 9 to 10 per centimeter distally. The sicula is 2.0 to 2.8 mm long, extends to the level of the aperture of th2 or above, and sometimes is ventrally curved. The ventral margin of th1 is slightly sigmoidally curved.

Discussion.—These specimens vary in details but are all about the same size and shape. They resemble *P. dubius* in size, thecae, and proximal ventral curvature. They differ from *P. dubius* mainly in having longer siculae and more thecae per centimeter proximally.*Occurrences.*—Collections 69ACn423, 70ACn552, 70ACn652, 70AR6g, and 70AR6h; approximately *Monograptus ludensis* Zone.

Pristiograptus cf. P. jaegeri Holland, Rickards, and Warren

Figures 47*E*, *N–P*

cf. *Pristiograptus jaegeri* Holland, Rickards, and Warren, 1969, p. 668–671, pl. 130, fig. 1, text-figs. 2k–r, 3f.

Description.—The rhabdosome is slender and nearly straight, as much as 3 cm long, and widens from 0.7 to 0.8 mm at the aperture of th1, through about 1.0 mm at th5, to a maximum of 1.5 to 1.9 mm distally. The thecae are pristiograptid and number 6 in 5 mm proximally, 8 to 9 per centimeter distally. The sicula is 2.1 to 3.0 mm long and usually extends to the level of the aperture of th3.

Discussion.—The Alaskan specimens match *P. jaegeri* in size, thecal spacing, and the straight rhabdosome. They differ in having a longer sicula (2 mm long, reaching the aperture of th2 in *P. jaegeri*) and distal thecae inclined to the rhabdosome axis at a smaller angle (about 30° compared to about 40° in *P. jaegeri*).

Occurrences.—Collections 70AR6b and 70AR6g; approximately *Monograptus ludensis* Zone. *P. jaegeri* occurs in the *M. ludensis* Zone in the British Isles (Holland and others, 1969; Rickards, 1976), the *Neodiversograptus nilssoni* Zone in Poland (Holland and others, 1969), and the *M. ludensis* Zone in central Nevada (Berry and Murphy, 1975, p. 41).

Pristiograptus cf. P. pseudodubius (Bouček)

Figures 48*A–C*

cf. *Monograptus pseudodubius* Bouček, 1932, p. 154, figs. 2e, f.
cf. *Pristiograptus pseudodubius* (Bouček). Přibyl, 1944, p. 8–9, pl. 1, fig. 8, text fig. 1, fig. 3. Rickards, 1965, p. 259–260, pl. 29, fig. 10, text-fig. 2i.

Description.—The rhabdosome is short and narrow with slight ventral curvature throughout. It measures as much as 8.5 mm long, 0.6 mm wide at the aperture of th1, and 0.9 to 1.1 mm wide distally. The pristiograptid thecae number 6 in 5 mm and overlap a little less than half their length. The sicula is 1.4 to 1.7 mm long and extends to the level of the first thecal aperture or a bit above.

Discussion.—The Terra Cotta Mountains specimens agree with *P. pseudodubius* in the size and shape of their rhabdosomes, but *P. pseudodubius* has only 9 1/2 to 11 thecae per centimeter and its sicula extends nearly to the level of th2. *P. pseudodubius* is narrower and shorter than *P. d. dubius*.

Occurrences.—Collections 69ACn431, 70ACn91, 70ACn111, 70AR7a, and 70AR8a; *Monograptus digitatus* Zone. *P. pseudodubius* occurs in the *Cyrtograptus lundgreni* and *Gothograptus nassa* Zones in the British Isles (Rickards, 1965; 1976) and the upper Wenlockian of Bohemia (Bouček, 1932).

Pristiograptus regularis regularis (Törnquist)

Figure 48*D*

Monograptus regularis Törnquist, 1899, p. 7, pl. 1, figs. 9–14. Elles and Wood, 1901–1918, p. 372–373, pl. 37, figs. 3a–d, text figs. 243*a–c*. Sherwin, 1974, p. 157–158, pl. 11, fig. 10, text-fig. 2e.
Pristiograptus regularis regularis (Törnquist). Rickards, 1970, p. 59–60, pl. 5, fig. 4, text-fig. 16, fig. 16. Hutt, 1975, p. 58–59, pl. 11, fig. 10, pl. 12, fig. 4, text-fig. 14, fig. 7.
Monograptus regularis regularis Törnquist. Bjerreskov, 1975, p. 47.
Pristiograptus regularis (Törnquist). Lenz, 1982. p. 60–61, figs. 5H–J, 21A–C. Chen, 1983, p. 60–61, pl. 10, fig. 10.

Diagnosis.—Rhabdosome straight and rigid, as long as 30 cm; width 0.3 to 0.4 mm at th1, increasing slowly to a maximum of 1.3 to 1.5 mm distally. Sicula 1.0 mm long. Thecae number 10 to 13 per centimeter proximally, 8 to 9 per centimeter distally.

Discussion.—*P. r. regularis* resembles *P. nudus* (Lapworth) but differs in being more slender proximally and having greater thecal overlap distally.

Occurrences.—Collections 70ACn152 and 70ACn412; *Monograptus turriculatus* Zone. *M. convolutus* through *M. turriculatus* Zones (Road River Formation) in the northern Yukon Territory, Canada (Lenz, 1982). *M. convolutus* Zone in Sweden (Törnquist, 1899) and Denmark (Bjerreskov, 1975). *M. convolutus* through *M. turriculatus* Zones in the British Isles (Rickards, 1976). Late Llandoverian in New South Wales, Australia (Sherwin, 1974). *M. turriculatus* Zone (Nanjiang Formation) in China (Chen, 1983).

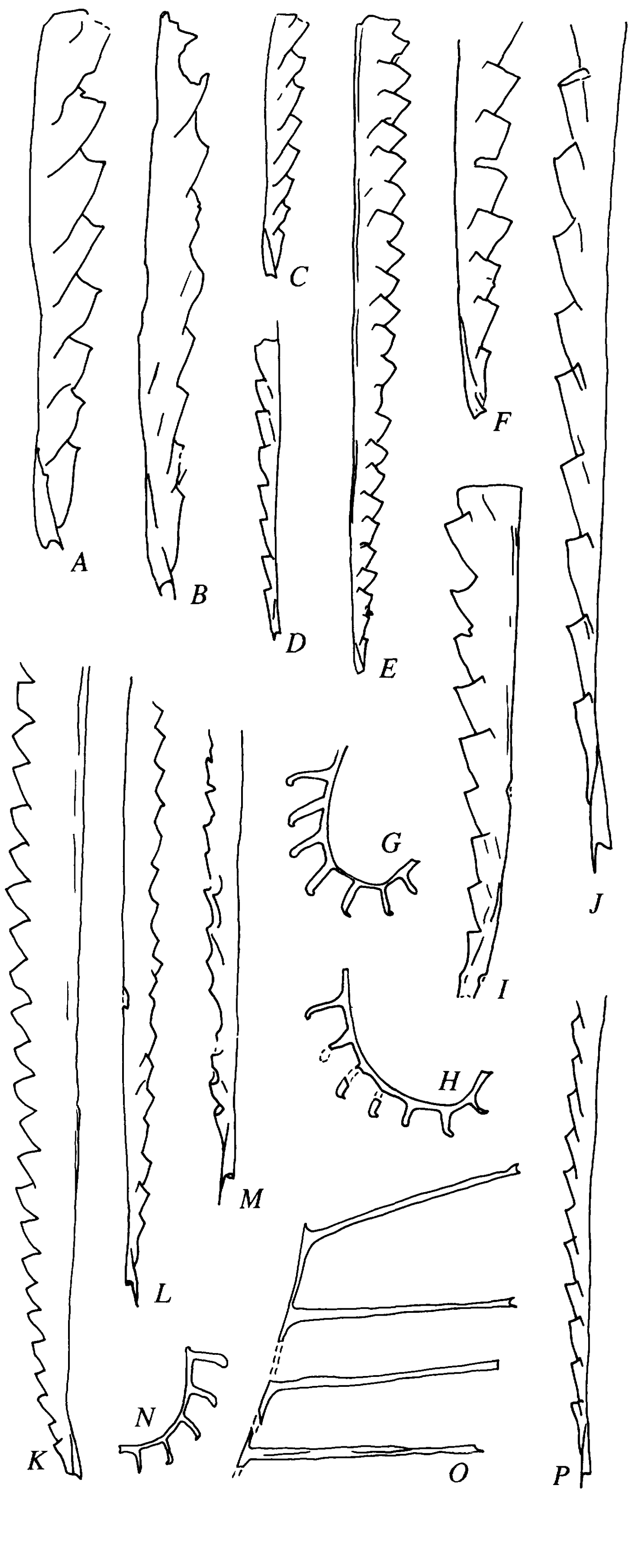
Pristiograptus sp. A

Figures 48*E, F, I*

Description.—The rhabdosome is at least 19 mm long, straight or with slight ventral curvature in the proximal 2 mm, widening rapidly from 0.4 mm at th1 to a maximum of 1.5 mm at about 12 mm from the proximal end. The thecae are of the pristiograptid type, relatively broad tubes overlapping about half their length distally, numbering 7 in 5 mm proximally and 12 per centimeter distally. The sicula is 1.4 to 1.5 mm long and extends almost to the level of the second thecal aperture. Th1 is much smaller (narrower) than the succeeding thecae and is less inclined to the rhabdosome axis.

Discussion.—This form resembles *P. nudus* (Lapworth) in its general size and nearly straight rhabdosome but differs in its ventrally curved proximal end, its longer sicula, and its more closely spaced thecae.

Occurrence.—Collection 70ACn412; *Monograptus turriculatus* Zone.



◀ **Figure 48.** *Pristiograptus* and *Rastrites*. ***A–C***, *P.* cf. *P. pseudodubius* (Bouček), all from USGS colln. 70AR8a: ***A***, ***C***, USNM 379243, ×10 and ×5, respectively; ***B***, USNM 379244, ×10. ***D***, *P. regularis regularis* (Törnquist), USNM 379245, USGS colln. 70ACn412, ×5. ***E***, ***F***, ***I***, *P.* sp. A, all from USGS colln. 70ACn412: ***E***, ***F***, USNM 379246, ×5 and ×10, respectively; ***I***, USNM 379247, ×10. ***G***, ***H***, ***N***, *R.* cf. *R. hybridus* Lapworth, all ×5: ***G***, USNM 379251, USGS colln. 70ACn621; ***H***, USNM 379252, USGS colln. 70ACn621; ***N***, USNM 379253, USGS colln. 69ACn341. ***J***, ***P***, *P.* sp. C, USNM 379249, USGS colln. 69ACn423, ×10 and ×5, respectively. ***K***, *P.* sp. B, USNM 379248, USGS colln. 70ACn412, ×5. ***L***, ***M***, *P.* sp. C?, USNM 379250 (part and counterparts), USGS colln. 69ACn423, ×5. ***O***, *R. linnaei* Barrande, USNM 379254, USGS colln. 70ACn412, ×5. Dashed line is extrapolation of missing part of rhabdosome.

Pristiograptus sp. B

Figure 48*K*

Description.—The rhabdosome is more than 3 cm long and straight except for the pronounced dorsal curvature in the first 2 mm of its length. It widens rapidly from 0.6 mm at the aperture of th1, through 1.1 mm at th5, to a maximum of 2.2 mm at th18. The thecae are pristiograptid and number 6 1/2 in 5 mm proximally and 8 1/2 per centimeter distally. The sicula is about 1.3 mm long and extends to the level of the first thecal aperture.

Discussion.—This form (a single specimen) is distinguished from other pristiograptids by its rapidly widening rhabdosome and proximal dorsal curvature.

Occurrence.—Collection 70ACn412; *Monograptus turriculatus* Zone.

Pristiograptus sp. C

Figures 48*J, P*

Description.—The rhabdosome is straight, at least 15 mm long, and widens from 0.3 mm at th1, through 0.75 mm at th5, to a distal maximum of 1.0 mm. The straight simple thecae number 4 in 5 mm proximally, increasing to 4 1/2 in 5 mm distally. Thecal overlap increases from almost none proximally to about one-third distally. The sicula is 1.5 mm long, extending approximately halfway up th1, which arises only about 0.8 mm down from the apex of the sicula.

Discussion.—Associated with the only specimen of this form in our collections is a specimen (figs. 48*L, M*) of similar characteristics but differing by being wider (0.5 mm at th1, 0.9 mm at th5, 1.1 mm maximum), having a longer sicula (about 2 mm), and having thecae more closely spaced (5 1/2 in 5 mm proximally). Both specimens differ from known species of *Pristiograptus* at this horizon by being very slender and straight. *P. regularis*, a similarly slender, straight species, has a shorter sicula, and its first theca originates nearer to the aperture of the sicula.

Occurrence.—Collection 69ACn423; approximately *Monograptus ludensis* Zone.

Genus *Rastrites* Barrande, 1850

Rastrites cf. *R. hybridus* Lapworth

Figures 48*G, H, N*

cf. *Rastrites peregrinus* var. *hybridus* Lapworth, 1876a, p. 313, pl. 10, fig. 5.

cf. *Monograptus* (*Rastrites*) *hybridus* (Lapworth). Elles and Wood, 1901–1918, p. 491, pl. 50, figs. 4a–f, text figs. 346*a, b*.

Description.—The rhabdosome is small and arcuate proximally, becoming nearly straight distally. The thecae are on the convex margin, numbering about 10 per centimeter, slightly declined, with their apertural regions reflexed into well-defined barbs. Th1 is 0.8 mm high, th2 is 0.8 to 0.9 mm high with the protheca 0.7 to 0.9 mm long, and th5 is 1.2 mm high with the protheca 0.9 to 1.0 mm long; the maximum (meta)thecal height is 1.4 mm with an average prothecal length of 1.0 mm. The sicula is about 1.0 mm long.

Discussion.—The Terra Cotta Mountains specimens closely resemble *R. hybridus* in the size and shape of their thecae and the general shape of the rhabdosome, but they are more strongly recurved proximally than Elles and Wood's (1901–1918) illustrated specimens, and their proximal thecae are more closely spaced (shorter prothecae). Their shorter, conspicuously barbed metathecae serve to distinguish them from *R. peregrinus* (Barrande).

Occurrences.—Collections 69ACn341 and 70ACn621; horizon indeterminate—they are associated in float collections with faunas of *Monograptus turriculatus* and *M. spiralis* Zones. *R. hybridus* occurs in the *M. convolutus* through *R. maximus* Zones in the British Isles (Rickards, 1976).

Rastrites linnaei Barrande

Figure 48*O*

Rastrites linnaei Barrande, 1850, p. 65, pl. 4, figs. 2, 4. Linnarsson, 1881, p. 520–521, pl. 23, figs. 22, 23. Törnquist, 1907, p. 14–15, pl. 2, figs. 22–26. Přibyl, 1941, p. 10–11, text fig. 1, figs. 1–3, pl. 2, figs. 1, 2, pl. 3, figs. 1–8. Schauer, 1967, p. 180–182, pl. 5, figs. 1–8. Rickards, 1970, p. 94–96, text-fig. 16, fig. 13. Sherwin, 1974, p. 173, pl. 11, fig. 13, pl. 12, fig. 7, text-fig. 2F. Bjerreskov, 1975, p. 83, text fig. 24A. Sennikov, 1976, p. 222–224, pl. 17, fig. 3. Lenz, 1982, p. 128, figs. 35B, D. Chen, 1983, p. 67, pl. 13, figs. 4, 11, 15.

Monograptus (*Rastrites*) *linnaei* (Barrande). Elles and Wood, 1901–1918, p. 493–494, pl. 51, figs. 1a–c, text figs. 349*a, b*.

Diagnosis.—Rhabdosome arcuate proximally, gently curved distally, with thecae on convex margin. Thecae number 6 to 4 per centimeter; maximum metathecal height about 8 mm.

Discussion.—The Alaskan specimens are apparently distal fragments only. Their metathecae are 6.5 to 7.0 mm high, and the prothecae are 2.0 to 2.2 mm long (5 to 4 1/2 thecae per centimeter). *R. linnaei* is distinguished from the similar form *R. maximus* Carruthers by having shorter, more closely spaced thecae.

Occurrences.—Collection 70ACn412; *Monograptus turriculatus* Zone. *M. sedgwickii* and *M. turriculatus* Zones (Road River Formation) in the northern Yukon Territory, Canada (Lenz, 1982). *Rastrites maximus* and *M. turriculatus* Zones in the British Isles (Rickards, 1976). *M. sedgwickii* and *Spirograptus minor* Zones in the Altai Mountains, the former USSR (Sennikov, 1976). *M. turriculatus* Zone in Denmark (Bjerreskov, 1975). Upper Llandoverian in New South Wales, Australia (Sherwin, 1974). Zones of *M. sedgwickii* and *S. turriculatus* in China (Chen, 1983).

FAMILY CYRTOGRAPTIDAE Bouček, 1933
Genus *Cyrtograptus* Carruthers, 1867
***Cyrtograptus* sp. aff. *C. lundgreni* sensu Lenz**

Figures 49*A*, *B*

Cyrtograptus sp. (aff. *C. lundgreni*), Lenz, 1978, p. 631, pl. 4, figs. 1, 4, 6.

Description.—The rhabdosome is small and broadly curved through less than 360°. The width gradually increases in the proximal portion from 0.5 mm at the aperture of th1 to a maximum of 1.0 mm at about th10 and is thereafter maintained. The first (and only) cladium is short and arises at th14 to 16. The thecae are on the convex margin of the main stipe proximal to the cladium, then the stipe twists so that the

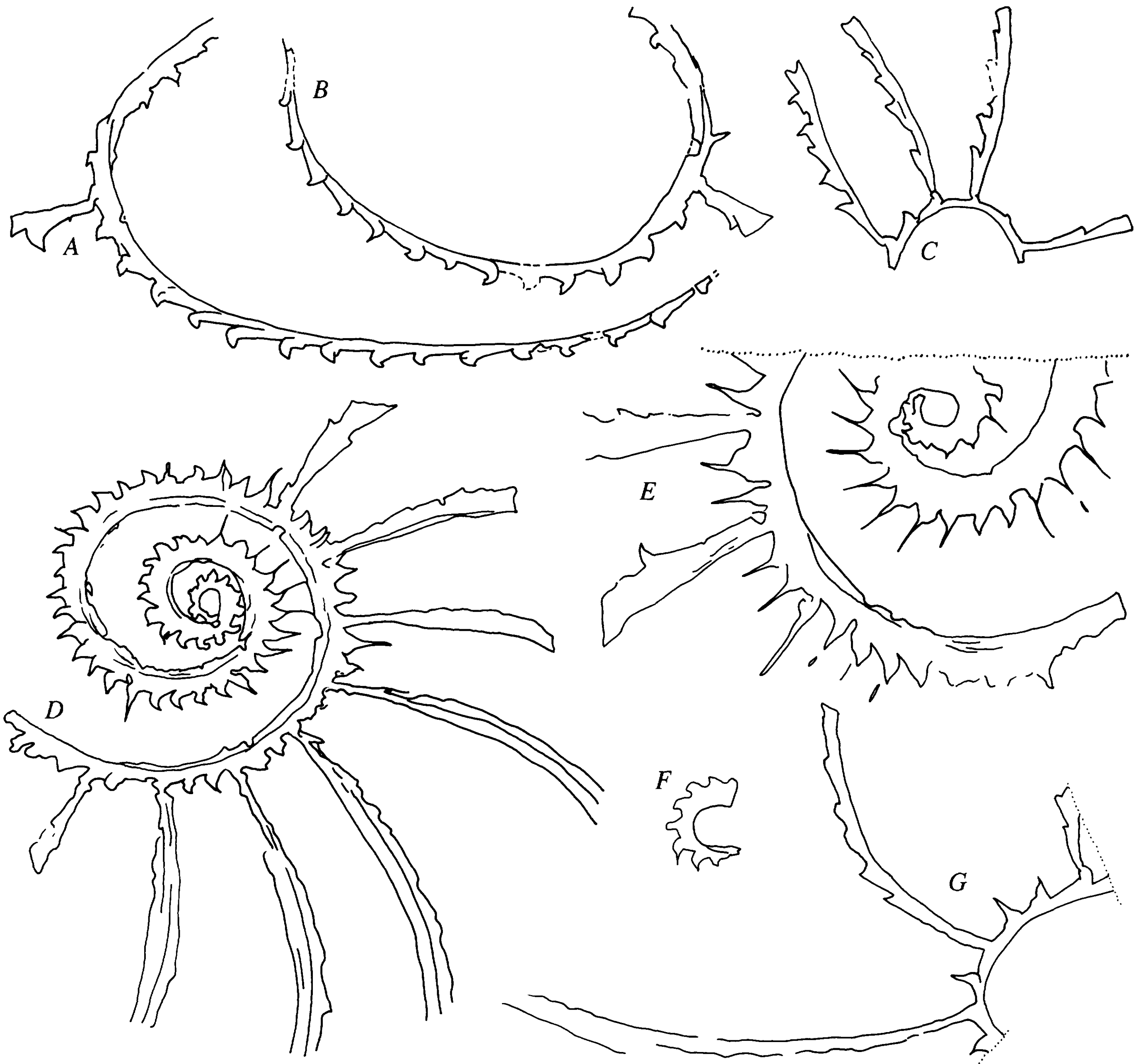


Figure 49. *Cyrtograptus*. ***A***, ***B***, *C*. sp. aff. *C. lundgreni* sensu Lenz, USGS colln. 76ACn292, ×5: ***A***, USNM 379255; ***B***, USNM 379256. ***C***, ***G***, *C*. cf. *C. mancki* Bouček, ×5: ***C***, USNM 379260, USGS colln. 69ACn373; ***G***, USNM 379261, USGS colln. 70ACn755. ***D–F***, *C. sakmaricus* Koren': ***D***, USNM 379257, USGS colln. 69ACn461, ×3.5; ***E***, USNM 379258, USGS colln. 69ACn452, ×5; ***F***, USNM 379259, USGS colln. 69ACn461, ×5, proximal fragment. Dotted line indicates edge of rock surface; dashed line is extrapolation of missing part of rhabdosome.

thecae are on the concave margin. The thecae are strongly hooked and a few bear very short apertural spines; they number 3 1/2 to 4 1/2 in 5 mm throughout the length of the rhabdosome.

Discussion.—The Terra Cotta Mountains specimens closely resemble Lenz's (1978) *Cyrtograptus* sp. (aff. *C. lundgreni*). Both forms differ from *C. lundgreni* Tullberg by having fewer thecae per centimeter and a narrower and more tapering proximal portion. In addition, Lenz's form gives rise to the cladium on th16 to 20 (as compared to th10 to 15 in *C. lundgreni*). One of the Terra Cotta Mountains specimens (fig. 49*A*) conforms with this parameter while the other one does not.

Occurrences.—Collection 76ACn292; *Cyrtograptus sakmaricus–C. laqueus* Zone. Lenz (1978) reports this form from the uppermost Llandoverian and the *C. centrifugus* (Wenlockian) Zone in northern and Arctic Canada.

Cyrtograptus cf. *C. mancki* Bouček

Figures 49*C*, *G*

cf. *Cyrtograptus mancki* Bouček, 1931, p. 305, fig. 15C. Lenz, 1978, p. 631–632, pl. 4, figs 2, 3.

Description:—The two Terra Cotta Mountains specimens are poorly preserved and fragmentary, but their main stipes appear to have been curved into a whorl about 5 mm in diameter. The main stipe is 0.7 to 1.2 mm wide and bears triangular thecae spaced at the rate of 10 per centimeter. The cladia are irregularly flexed or gently dorsally curved, 0.7 to 0.8 mm wide, as much as 1.5 cm long, and usually arise from every second or third theca. The interval between th1 and the first cladium is unknown. The cladial thecae are not as triangular as those on the main stipe, and they number 10 per centimeter.

Discussion.—In its small size and closely spaced cladia, the Terra Cotta Mountains form resembles *C. mancki*. It differs in the cladial spacing, which is not regular (as compared to a cladium on every second theca in *C. mancki*). In this respect, the Terra Cotta Mountains form is closer to *C.* cf. *C. mancki* described by Lenz (1978, p. 631, pl. 4, fig. 5) and to *C.* sp. aff. *C. mancki* described by Berry and Murphy (1975, p. 93, pl. 8, fig 7).

Occurrences.—Collections 69ACn373 and 70ACn755; *C. lundgreni* Zone. *C. mancki* occurs in the *Monograptus testis–C. lundgreni* Zone of northern Canada (Lenz, 1978) and the *M. testis* Zone of the former Czechoslovakia (Bouček, 1931).

Cyrtograptus sakmaricus Koren'

Figures 49*D–F*

Cyrtograptus sakmaricus Koren', 1968, p. 102–103, fig. 2. Lenz, 1978, p. 633, pl. 2, fig. 4.

Cyrtograptus canadensis Jackson and Etherington, 1969, p. 1115–1118, pl. 129, figs. 1–3, text-figs. 1A–D.

Cyrtograptus cf. *C. sakmaricus* Koren'. Berry and Murphy, 1975, p. 90–91, pl. 12, figs. 1, 2, pl. 13, fig. 2.

Diagnosis.—Main stipe spiral, coiled through at least 2 1/2 volutions, becoming slightly curved or almost straight distally. Diameter of spiral 15 to 20 mm. First cladium arises at th35 to 45, followed by 7 to 15 additional simple (unbranched) cladia at intervals of 3 to 4 thecae. Width of main stipe increases from 0.3 to 0.5 mm initially to maximum of 1.7 to 2.0 mm distally. Thecae of *Monograptus spiralis* type, subtriangular with hooked apertural regions and long apertural spines, spaced 8 to 12 per centimeter. Cladia curved to nearly straight, as long as 13 cm, widening from 0.3 to 0.5 mm initially to 1.5 to 2.0 mm distally, bearing 9 to 10 thecae per centimeter.

Discussion.—The Alaskan specimens agree well with the above diagnosis of *C. sakmaricus* except that in one (fig. 49*D*), the first cladia does not appear until about th54. An associated proximal fragment (fig. 49*F*), believed to be of the same species, has a sicula measuring 1.0 mm long.

Occurrences.—Collections 69ACn452 and 69ACn461; *C. sakmaricus–C. laqueus* Zone. Upper Llandoverian to lower Wenlockian in southern Ural Mountains, former USSR (Koren', 1968). *C. sakmaricus–C. laqueus* Zone in northwestern Canada (Lenz, 1978). *C.* cf. *C. sakmaricus* Zone in central Nevada (Berry and Murphy, 1975).

Genus *Barrandeograptus* Bouček, 1933

Barrandeograptus? *bornholmensis* (Laursen)

Figure 50*C*

Cyrtograptus bornholmensis Laursen, 1940, p. 30, 35–36, pl. 3, figs. 1–4.

Barrandeograptus? *bornholmensis* (Laursen). Bjerreskov, 1975, p. 89, fig. 27B.

Diagnosis.—Rhabdosome slender; width does not exceed 0.75 mm , averages about 0.5 mm. Cladia may be up to third order. Thecae axially elongated and isolated, with rounded apertures, spaced at 6 to 7 per centimeter.

Discussion.—The single Terra Cotta Mountains specimen has stipes 0.3 to 0.5 mm wide with thecae numbering 7 per centimeter. It is only a fragment with a single cladium and is not well enough preserved to reveal the true nature of its thecal apertures. *B.*? *bornholmensis* resembles *B. pulchellus* (Tullberg) but is narrower than that species.

Occurrences.—Collection 70ACn173; *Cyrtograptus centrifugus* Zone. *C. centrifugus* Zone on Bornholm, Denmark (Bjerreskov, 1975).

Barrandeograptus? sp.

Figures 50*A*, *B*

Description.—The rhabdosome consists of a flexuous main stipe more than 7 cm long and four nearly straight branches (cladia?) 13 to 18 mm long. The width of the main stipe and branches is 0.1 to 0.3 mm. The thecae appear to be of the *Barrandeograptus* type, simple tubes with no overlap and straight ventral walls inclined only about 10° to the axis of the rhabdosome, numbering 8 to 10 per centimeter. The nature of the thecal apertures cannot be determined. The simple branches all arise on the same side of the main stipe at intervals of 6.3 to 8.0 mm. (On figure 50*B*, torsion of the main stipe between the third and fourth branches has caused the appearance of branching on both sides.) The sicula has not been detected.

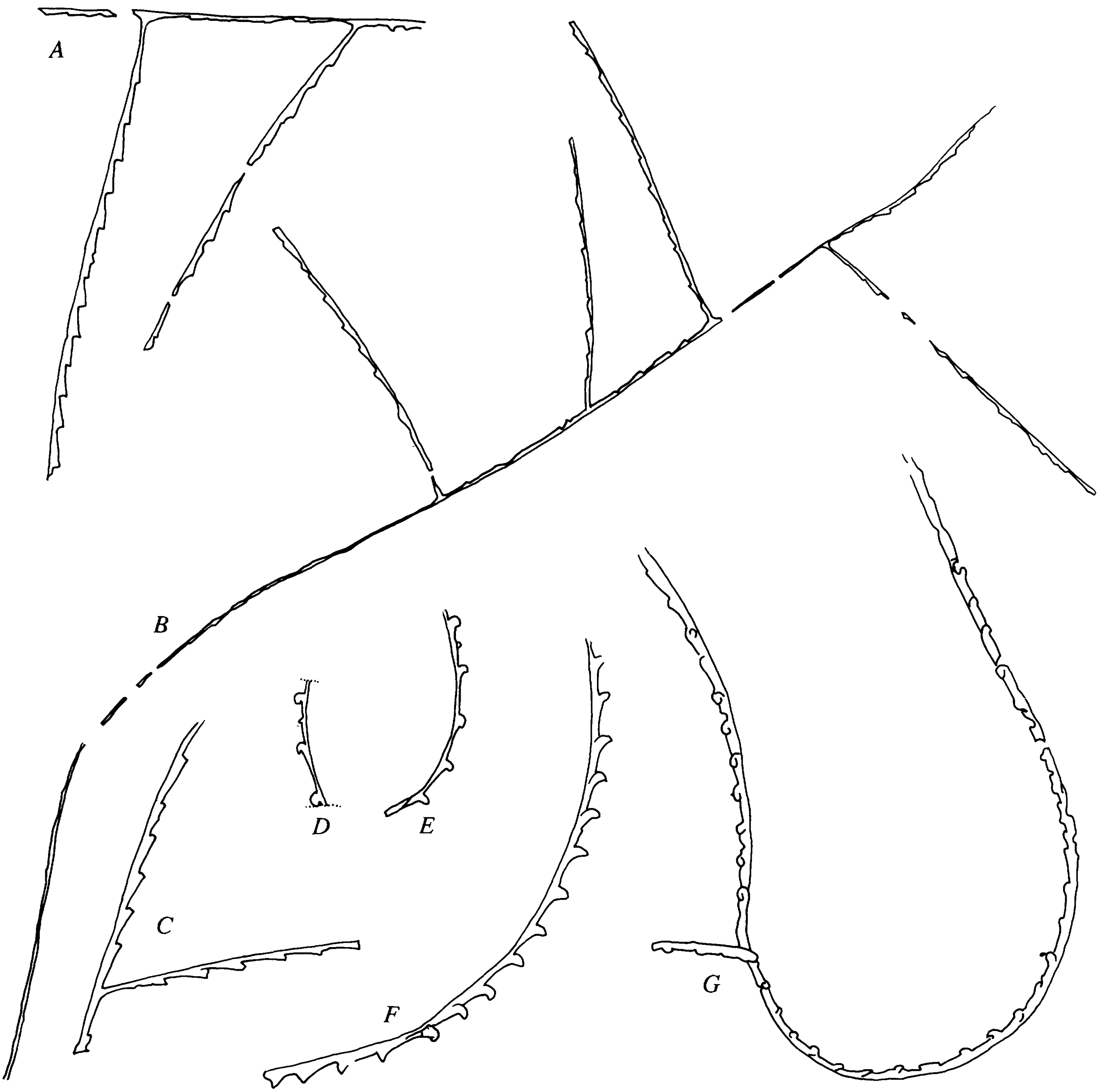


Figure 50. *Barrandeograptus*?, *Diversograptus*, and *Sinodiversograptus*?. ***A***, ***B***, *B.*? sp., USNM 379263, USGS colln. 70ACn412, ×5 and ×3.5, respectively. ***C***, *B.*? *bornholmensis* (Laursen), USNM 379262, USGS colln. 70ACn173, ×5. ***D–F***, *D. ramosus* Manck, all ×5: ***D***, USNM 379264, USGS colln. 69ACn362; ***E***, USNM 379265, USGS colln. 69ACn362; ***F***, USNM 379266, USGS colln. 69ACn341. ***G***, *S.*? sp., USNM 379267, USGS colln. 70ACn412, ×5.

Discussion.—The single Terra Cotta Mountains specimen is distinguished by the extreme narrowness of its main stipe and branches. The shape of the thecae and the presence of cladial(?) branches cause its tentative referral to *Barrandeograptus*, even though that genus usually occurs in considerably younger beds. However, Lenz (1982, p. 136) reports *Barrandeograptus* aff. *pulchellus* from the *M. sedgwickii* Zone in the northern Yukon Territory, Canada.

Occurrence.—Collection 70ACn412; *Monograptus turriculatus* Zone.

Genus *Diversograptus* Manck, 1923
***Diversograptus ramosus* Manck**

Figures 50*D–F*

Diversograptus ramosus Manck, 1923, p. 283–285, figs. 1.3–1.8. Bouček and Přibyl, 1953, p. 5–9, pl. 2, figs. 1–4, pl. 3, fig. 1, text fig. 1, figs. 6–12. Rickards, 1973, p. 184–185, figs. 15–17. ?Lenz, 1982, p. 135, figs. 3S–U, 37D, G–J.

Diversograptus bohemicus Bouček. Bouček and Přibyl, 1953, p. 563–564, pl. 3, figs. 4–8, text fig. 1, figs. 1–5.

Diversograptus capillaris pergracilis (Bouček). Bouček and Přibyl, 1953, p. 561–562, pl. 1, fig. 4, text fig. 2, figs. 1–6.

Diagnosis.—Rhabdosome very long and slender, commonly twisted, with variable curvature from almost straight to S-shaped and occasionally coiled, often bearing cladia at varying distances from sicula. Dorso-ventral width at th1 is 0.25 to 0.4 mm (mostly 0.25–0.3 mm), increasing very gradually to maximum width of 0.8 to 1.5 mm (mostly 0.8 mm). Thecae number 5 1/2 to 8 per centimeter proximally, 5 to 10 per centimeter distally. Prothecae elongate, with free ventral walls inclined only slightly to rhabdosome axis; metathecae retroverted into small *Monograptus priodon*-like hooks. Distally, thecae tend to become more like beaks than hooks. Sicula about 1 mm long.

Discussion.—The Terra Cotta Mountains specimen illustrated in figure 50*F* probably exhibits a pseudocladium rather than a sicular cladium because it is wider than is usual for the proximal portion of *D. ramosus* (see Rickards, 1973, p. 185, fig. 17). The proximal fragment illustrated in figure 50*E* is 0.4 to 0.5 mm wide and may be an example of the more robust form of *D. ramosus* mentioned by Rickards (1973, p. 185, fig. 16). *D. ramosus* is distinguished by its width and the form and spacing of its thecae. It closely resembles *D.? capillaris* (Carruthers) but is generally wider (compared to a maximum width of 0.4 mm in *D.? capillaris*).

Occurrences.—Collections 69ACn341 and 69ACn362; *Monograptus spiralis* Zone. *Diplograptus magnus* through *M. crenulata* Zones in the British Isles (Rickards, 1976). *Spirograptus spiralis* Zone in Bohemia and *M. sedgwickii* through *S. spiralis* Zones in Germany (Bouček and Přibyl, 1953).

Genus *Sinodiversograptus* Mu and Chen, 1962
***Sinodiversograptus*? sp.**

Figure 50*G*

Description.—The rhabdosome is bipolar, approximately U-shaped, outlining an area roughly 1 cm wide by 2 cm long. The sicula, if present, is not visible. Near the bipolar juncture is a branch that appears to be a thecal cladium. It arises on the ventral margin and immediately bends toward the dorsal margin, in the same manner as the cladia of *Sinodiversograptus*. Throughout its length, the stipe is 0.4 to 0.5 mm wide and has 9 to 10 thecae per centimeter. The thecae are like those of *S. multibrachiatus* Mu and Chen, with elongate prothecae generally parallel to the stipe axis and short, strongly hooked metathecae. The stipe twists so that the thecae are not continuously on the same margin, particularly at the bipolar juncture.

Discussion.—In the shape of the bipolar main stipe and the shape of the thecae, the Terra Cotta Mountains form agrees with *Sinodiversograptus*, but it apparently has only one thecal cladium in comparison to the multiple cladia of *Sinodiversograptus*. Lenz (1982, fig. 37D) has illustrated a specimen of *D.? ramosus* from the *Monograptus turriculatus* Zone of northern Canada that has a similar, bipolar, U-shaped rhabdosome and similar thecae, but its stipe is more strongly curved and wider than that of the Alaskan form and it lacks thecal cladia.

Occurrence.—Collection 70ACn412; *M. turriculatus* Zone.

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