Ordovician and Silurian Phi Kappa and Trail Creek Formations, Pioneer Mountains, Central Idaho—Stratigraphic and Structural Revisions, and New Data on Graptolite Faunas

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1090

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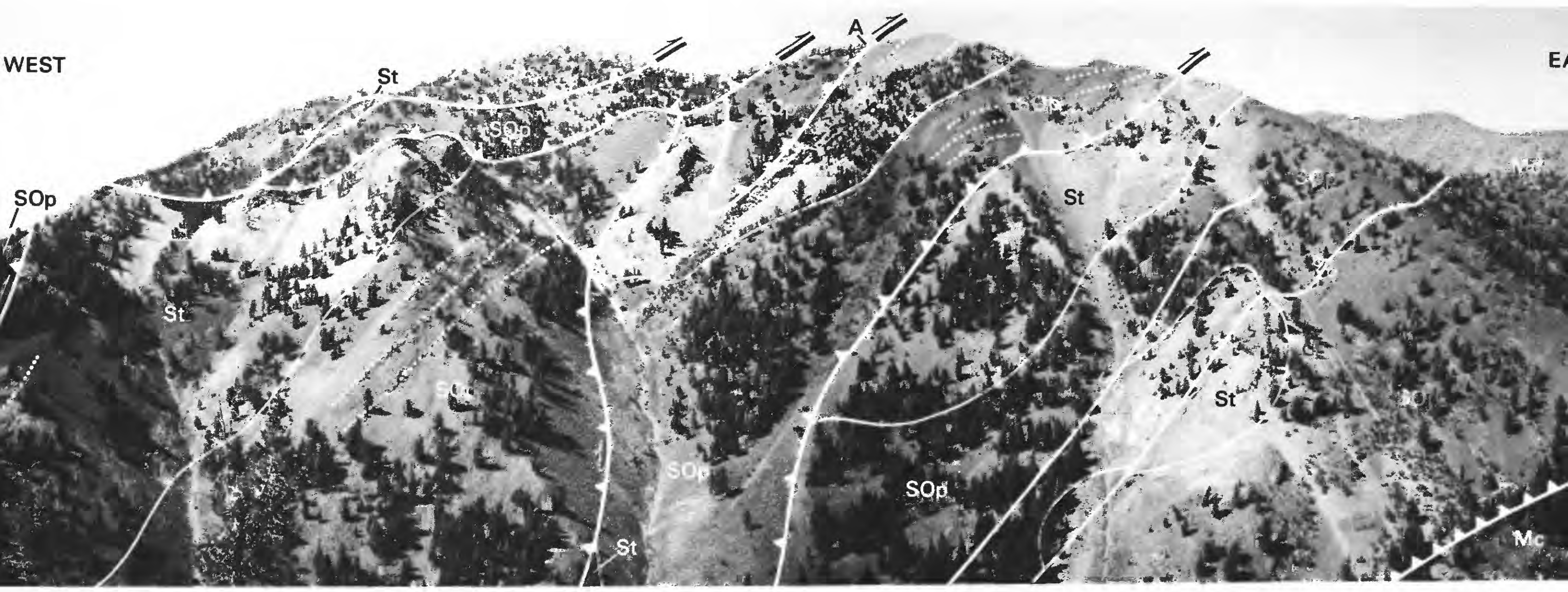

EXPLANATION

THRUST FAULT—Showing relative movement. Teeth on upper plate

FAULT—Showing relative movement (D, U)

APPROXIMATE BEDDING TRACE

Frontispiece.—Imbricate thrust slices of the Phi Kappa (SOp) and Trail Creek (St) Formations on the ridge between Park and Little Fall Creeks, Pioneer Mountains, Idaho. The imbricated Phi Kappa-Trail Creek allochthon moved eastward over deformed clastic rocks of the Mississippian Copper Basin Formation (Mc in lower right and distant ridge). Silurian and Devonian rocks (DSr) overrode the Phi Kappa-Trail Creek allochthon from the west. One of the three sections originally measured for the Phi Kappa Formation by Westgate and C. P. Ross (1930), called the Park Creek ridge section in this report, extends eastward from point A along the ridge crest and beyond the right edge of the photograph, where it crosses the sole thrust of the Phi Kappa-Trail Creek allochthon (thrust fault with close-spaced teeth).

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By JAMES H. DOVER, W. B. N. BERRY, *and* R. J. ROSS, JR.

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METRIC-ENGLISH EQUIVALENTS

[SI, International System of Units, a modernized metric system of measurement]

SI unit		U.S. customary equivalent	
Length			
millimeter (mm)	=	0.039 37	inch (in)
meter (m)	=	3.281	feet (ft)
	=	1.094	yards (yd)
kilometer (km)	=	0.621 4	mile (mi)
	=	0.540 0	mile, nautical (nmi)
Area			
centimeter² (cm²)	=	0.155 0	inch² (in²)
meter² (m²)	=	10.76	feet² (ft²)
	=	1.196	yards² (yd²)
	=	0.000 247 1	acre
hectometer² (hm²)	=	2.471	acres
	=	0.003 861	section (640 acres or 1 mi²)
kilometer² (km²)	=	0.386 1	mile² (mi²)
Volume			
centimeter³ (cm³)	=	0.061 02	inch³ (in³)
decimeter³ (dm³)	=	61.02	inches³ (in³)
	=	2.113	pints (pt)
	=	1.057	quarts (qt)
	=	0.264 2	gallon (gal)
	=	0.035 31	foot³ (ft³)
meter³ (m³)	=	35.31	feet³ (ft³)
	=	1.308	yards³ (yd³)
	=	264.2	gallons (gal)
	=	6.290	barrels (bbl) (petroleum, 1 bbl=42 gal)
	=	0.000 810 7	acre-foot (acre-ft)
hectometer³ (hm³)	=	810.7	acre-feet (acre-ft)
kilometer³ (km³)	=	0.239 9	mile³ (mi³)
Volume per unit time (includes flow)			
decimeter³ per second (dm³/s)	=	0.035 31	foot³ per second (ft³/s)
	=	2.119	feet³ per minute (ft³/min)
	=	15.85	gallons per minute (gal/min)
	=	543.4	barrels per day (bbl/d) (petroleum, 1 bbl=42 gal)
meter³ per second (m³/s)	=	35.31	feet³ per second (ft³/s)
	=	15 850	gallons per minute (gal/min)
Mass			
gram (g)	=	0.035 27	ounce avoirdupois (oz avdp)
kilogram (kg)	=	2.205	pounds avoirdupois (lb avdp)
megagram (Mg)	=	1.102	tons, short (2 000 lb)
	=	0.984 2	ton, long (2 240 lb)
Mass per unit volume (includes density)			
kilogram per meter³ (kg/m³)	=	0.062 43	pound per foot³ (lb/ft³)
Pressure			
kilopascal (kPa)	=	0.145 0	pound-force per inch² (lbf/in²)
	=	0.009 869	atmosphere, standard (atm)
	=	0.01	bar
	=	0.296 1	inch of mercury at 60°F (in Hg)
Temperature			
temp kelvin (K)	=	[temp deg Fahrenheit (°F) +459.67]/1.8	
temp deg Celsius (°C)	=	[temp deg Fahrenheit (°F) −32]/1.8	

ORDOVICIAN AND SILURIAN PHI KAPPA AND TRAIL CREEK FORMATIONS, PIONEER MOUNTAINS, CENTRAL IDAHO—STRATIGRAPHIC AND STRUCTURAL REVISIONS, AND NEW DATA ON GRAPTOLITE FAUNAS

By JAMES H. DOVER, W. B. N. BERRY, *and* R. J. ROSS, JR.

ABSTRACT

Recent geologic mapping in the northern Pioneer Mountains combined with the identification of graptolites from 116 new collections indicate that the Ordovician and Silurian Phi Kappa and Trail Creek Formations occur in a series of thrust-bounded slices within a broad zone of imbricate thrust faulting. Though confirming a deformational style first reported in a 1963 study by Michael Churkin, our data suggest that the complexity and regional extent of the thrust zone were not previously recognized. Most previously published sections of the Phi Kappa and Trail Creek Formations were measured across unrecognized thrust faults and therefore include not only structural repetitions of graptolitic Ordovician and Silurian rocks but also other tectonically juxtaposed lithostratigraphic units of diverse ages as well. Because of this discovery, the need to reconsider the stratigraphic validity of these formations and their lithology, nomenclature, structural distribution, facies relations, and graptolite faunas has arisen.

The Phi Kappa Formation in most thrust slices has internal stratigraphic continuity despite the intensity of deformation to which it was subjected. As revised herein, the Phi Kappa Formation is restricted to a structurally repeated succession of predominantly black, carbonaceous, graptolitic argillite and shale. Some limy, light-gray-weathering shale occurs in the middle part of the section, and fine-grained locally pebbly quartzite is present at the base. The basal quartzite is here named the Basin Gulch Quartzite Member of the Phi Kappa. The Phi Kappa redefined on a lithologic basis represents the span of Ordovician time from W. B. N. Berry's graptolite zones 2–4 through 15 and also includes approximately 17 m of lithologically identical shale of Early and Middle Silurian age at the top. The lower contact of the formation as revised is tectonic. The Phi Kappa is gradationally overlain by the Trail Creek Formation as restricted herein. Most of the coarser clastic rocks reported in previously measured sections of the Phi Kappa, as well as the sequence along Phi Kappa Creek from which the name originates, are excluded from the Phi Kappa as revised and are reassigned to two structural plates of Mississippian Copper Basin Formation; other strata now excluded from the formation are reassigned to the Trail Creek Formation and to an unnamed Silurian and Devonian unit. As redefined, the Phi Kappa Formation is only about 240 m thick, compared with the 3,860 m originally estimated, and it occupies only about 25 percent of the outcrop area previously mapped in 1930 by H. G. Westgate and C. P. Ross. Despite this drastic reduction in thickness and the exclusion of the rocks along Phi Kappa Creek, the name Phi Kappa is retained because of widely accepted prior usage to denote the Ordovician graptolitic shale facies of central Idaho, and because the Phi Kappa Formation as revised is present in thrust slices on Phi Kappa Mountain, at the head of Phi Kappa Creek. The lithic and faunal consistency of this unit throughout the area precludes the necessity for major facies telescoping along individual faults within the outcrop belt. However, tens of kilometers of tectonic shortening seems required to juxtapose the imbricated Phi Kappa shale facies with the Middle Ordovician part of the carbonate and quartzite shale sequence of east central Idaho. The shelf rocks are exposed in the Wildhorse structural window of the northeastern Pioneer Mountains, and attain a thickness of at least 1,500 m throughout the region north and east of the Pioneer Mountains. The Phi Kappa is in direct thrust contact on intensely deformed medium- to high-grade metamorphic equivalents of the same shelf sequence in the Pioneer window at the south end of the Phi Kappa–Trail Creek outcrop belt. Along East Pass, Big Lake, and Pine Creeks, north of the Pioneer Mountains, some rocks previously mapped as Ramshorn Slate are lithologically and faunally equivalent to the Phi Kappa Formation as revised.

The Trail Creek Formation, as originally defined, was delineated primarily on the basis of the mid-Llandoverian to mid-Wenlockian age of the graptolite fauna in its basal argillite member. Previous workers apparently overlooked the predominance of the overlying buff-weathering, banded, siliceous metasiltstone in the section originally described. Structural repetitions of these rocks elsewhere in the area were misassigned to the lower part of the original Phi Kappa Formation or to a separate Middle Ordovician facies of the Phi Kappa. The consistent occurrence of the metasiltstone beds stratigraphically above uppermost Ordovician Phi Kappa strata can now be demonstrated or inferred from new fossil data in several superimposed thrust slices within the Ordovician-Silurian outcrop belt. We propose that the name Trail Creek be restricted to the banded metasiltstone that constitutes the bulk of the section originally described and represents a distinctive lithostratigraphic unit that can be mapped throughout the Ordovician-Silurian outcrop belt. The Silurian graptolitic argillite at the base of the original Trail Creek, which passes without lithologic break into Ordovician beds of the underlying Phi Kappa Formation as originally defined, are included in the redefined Phi Kappa because the formational boundary as previously drawn was based on a faunal change that cannot be mapped in the field without fossils. The name Trail Creek was previously applied to monograptid-bearing platy limestone and limy shale at Malm Gulch, 48 km to the north, that belongs to the Silurian part of the eastern carbonate shelf facies.

Detailed graptolite studies not only have been instrumental in unraveling the complex structural distribution of the Phi Kappa and Trail Creek Formations but also provide new data on the Middle Ordovician graptolite fauna of western North America. Collections made from two unbroken stratigraphic sequences demonstrate the continuity of Ordovician graptolite zones 6 (*Didymograptus protobifidus*) through 15 (*Dicellograptus complanatus*) of Berry. Ordovician graptolites older than zone 6 have been found at only a few localities. These collections demonstrate the presence of earlier Ordovician strata even though none has been shown to be in stratigraphic continuity with the younger Ordovician collections. In the late Early to early Middle Ordovician part of the two sections, beds containing isograptid and pseudisograptid-rich faunas gradationally overlie *Didymograptus protobifidus*-bearing beds. Isograptid faunas are succeeded stratigraphically by those in which *Diplograptus decoratus multus* is common and *Holmograptus nodosus* is present. In stratigraphically overlying layers, most dichograptids drop out and *Glyptograptus* cf. *G. euglyphus* appears. This faunal succession is analogous to the interval of W. B. N. Berry's zones 6 (*Didymograptus protobifidus*) through 10 (*Glyptograptus teretiusculus*) in the Marathon region, West Texas. The isograptid-pseudisograptid fauna includes some taxa, including subspecies of *I. caduceus* and *Pseudisograptus dumosus*, not recorded previously from North America but which are similar to species found in Australia and New Zealand. The pseudisograptids are much more common in one of the two sections examined closely than in the other, in a different thrust slice, where subspecies of *Glyptograptus austrodentatus* predominate in lithologically similar and coeval beds. These variations suggest that even geographically close and coeval faunas may be somewhat dissimilar, possibly because of local ecological variations.

INTRODUCTION

This report is an outgrowth of geologic mapping since 1964 by J. H. Dover in the Pioneer Mountains of central Idaho. In its initial stage, the mapping relied heavily on the work of three predecessors—L. G. Westgate and C. P. Ross (1930), who prepared the first comprehensive geologic map and report of the region and first defined the Phi Kappa and Trail Creek Formations, and Michael Churkin, Jr. (1963), who used graptolite zonations to document thrust faults within these formations in a key section near Trail Creek Summit. Mapping of lithologic and structural units alone proved inadequate in Dover's attempt to extend the structural sequences recognized by Churkin into other parts of the belt. Beginning in 1972, R. J. Ross, Jr., and W. B. N. Berry studied graptolites previously collected by Dover from localities distributed widely through the outcrop belt. From our preliminary effort to relate graptolite identifications and zone assignments to Dover's mapping, it appeared that the structure of the Phi Kappa and Trail Creek belt was considerably more complex than any of the previous workers had realized, and additional detailed collections were made in 1973 and 1974 by the authors to test the structural framework as we understood it then. These activities not only confirmed the complexity of the structure but also showed that previously published literature contains important misconceptions concerning the lithology, nomenclature, structural distribution, facies relations, and graptolite fauna of the Phi Kappa and Trail Creek Formations. Most of the stratigraphic problems are a result of structural complications not recognized in the previous reconnaissance work in the area. Dover's new mapping, combined with the identification by Berry and Ross of graptolites in collections from 116 localities, forms the basis of this report which is intended primarily to update and clarify present concepts of these formations in light of our new data.

In addition, Berry's detailed examination of graptolites in closely spaced collections from two stratigraphic sections reveals taxa not previously cited from North America. These are primarily late Early and early Middle Ordovician species of isograptids and pseudisograptids that are known from Australia and New Zealand. Although the number of specimens of these taxa is small, their presence in the Idaho fauna is significant to an understanding of graptolite evolution in North America. Also, the abundance of certain species of the same faunal assemblage differs in the two lithologically similar sections, and some possible explanations are discussed.

LOCATION AND ACCESS

The Ordovician and Silurian rocks considered here are in the northern Pioneer Mountains, mainly in the northeast part of the Rock Roll Canyon 7½-minute quadrangle, but extending into adjacent parts of the Phi Kappa Mountain and Meridian Peak 7½-minute quadrangles (pl. 1; fig. 1). The mapped area is about 16 km northeast of Ketchum, a town on U.S. Route 93 in the Big Wood River valley (pl. 1; fig. 1). The southern part of the area is crossed by a paved and improved gravel road that traverses the Pioneer Mountains via Trail Creek, Trail Creek Summit, Summit Creek, and Big Lost River and connects Ketchum and the resort of Sun Valley with Mackay on U.S. Route 93 Alternate in the Big Lost River Valley. Dirt or improved gravel roads branch from the main access route along Park and the upper part of Trail Creek, Little Fall Creek, Phi Kappa Creek, and North Fork of Big Lost River. The upper reaches of Summit, Phi Kappa, Trail, and Kane Creeks, and Miller and Squib Canyons can be reached by hikes of several miles on poorly maintained foot trails.

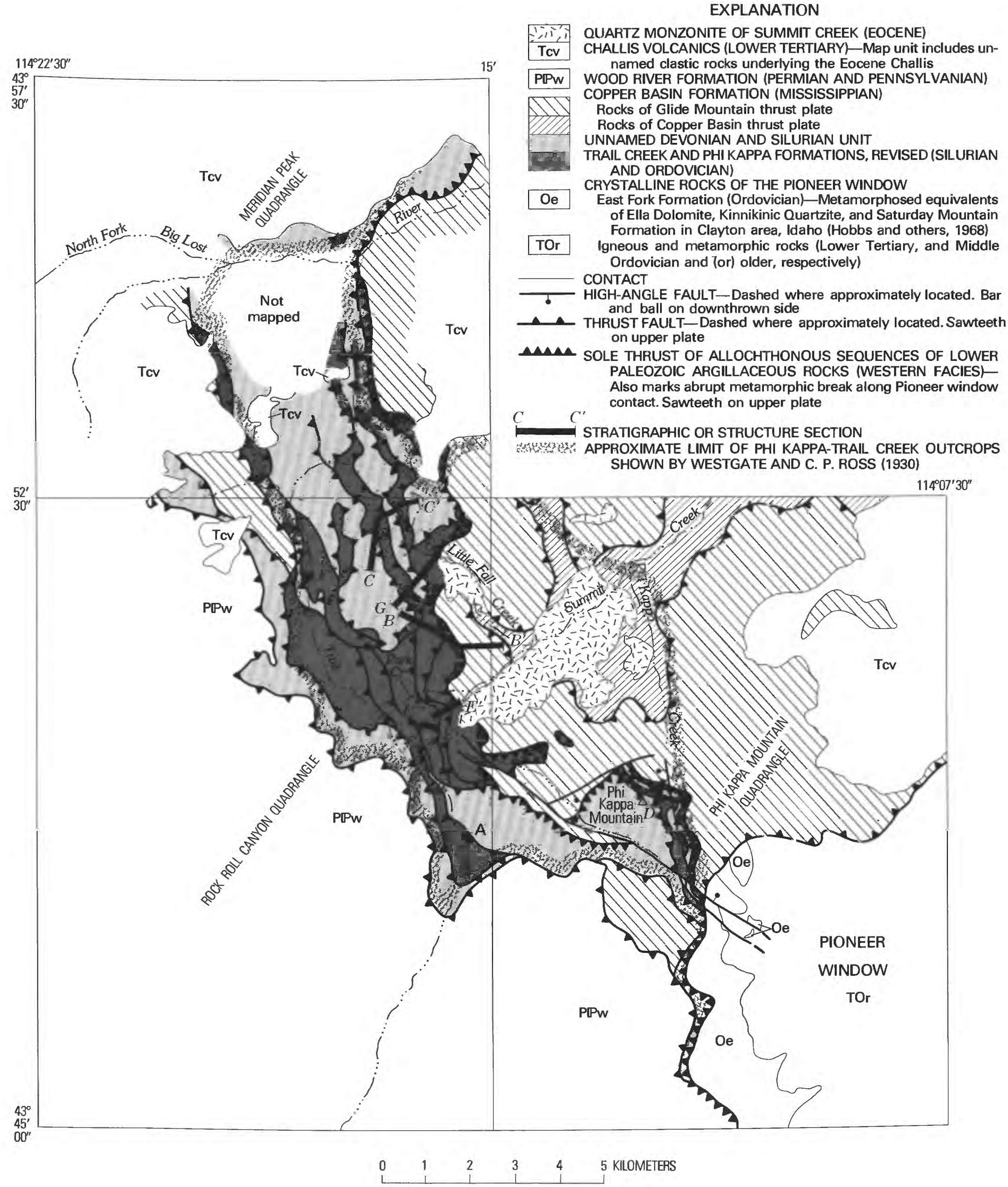

FIGURE 1.—Simplified geologic map of the northern Pioneer Mountains, Idaho, showing measured stratigraphic sections and key graptolite localities. Base modified from U.S. Geological Survey 1:24,000 quadrangles: Meridian Peak, Phi Kappa Mountain, and Rock Roll Canyon (1967). Mapped by James H. Dover, 1964–76; assisted by S. W. Hobbs, 1973.

PHYSIOGRAPHY

The physiography of the Pioneer Mountains region is described by Dover (1969) and Simons and others (1979). The part of the range discussed here is steep and forested. Altitudes range from about 2,000 m along lower Trail Creek to approximately 3,205 m (10,515 ft)[1] at the summit of Phi Kappa Mountain (pl. 1). Local relief of 600–900 m is common; the steepest topography is in the gorge along the middle part of Trail Creek and in the cirques north and east of upper Summit Creek. The topography is mainly glacial in origin and is not notably influenced by the distribution of lithologic units or structure.

PREVIOUS WORK

The first report of Ordovician rocks in the Pioneer Mountains was by Blackwelder (1913). Following the original work of Westgate and C. P. Ross (1930), Ruedemann (1947) listed graptolites collected by Edwin Kirk from the Phi Kappa and Trail Creek Formations in his treatise on North American graptolites. R. J. Ross, Jr., and Berry (1963) also included all material from the Phi Kappa Formation then available to them in their review of Ordovician graptolites of the Basin Ranges. At about the same time, the zonal distribution of new graptolite collections was described by Churkin (1963) in a structurally imbricated section of the Phi Kappa and Trail Creek Formations near Trail Creek Summit (pl. 1, sec. *E–E'*). Carter (1972) and Carter and Churkin (1977) reviewed graptolite zonation of the upper part of the Trail Creek Summit section. Reports on the bedrock geology of the northern and central Pioneer Mountains by Dover (1969, in press) include discussions of the Phi Kappa–Trail Creek outcrop belt. The geologic map of the Pioneer Mountains region by Dover and others (1976) encompasses the area of Phi Kappa–Trail Creek rocks considered here, and when compared with Dover's 1969 map, illustrates how stratigraphic and structural models of this complex area have evolved with the acquisition of new and more complete data. Though concentrated in an area about 25 km southeast of our map area, the work of Paull, Wolbrink, Volkmann, and Grover (1972) on the Mississippian rocks of Copper Basin has strongly influenced our proposed restrictions of the Phi Kappa Formation.

[1]All metric values converted from Foot-pound system. Metric values given represent mathematical equivalents and are not exact measurements. Measurements cited from previous reports or topographic maps that originally were given in the Foot-pound system are shown in parentheses after metric equivalent.

ACKNOWLEDGMENTS

The authors are indebted to Leonard Wilson for his assistance both in the collection and preparation of fossil materials in 1973 and 1974. S. W. Hobbs aided with geologic mapping in part of the Phi Kappa–Trail Creek outcrop belt during parts of the 1973 and 1974 field seasons; Jonathan Myers and G. V. Podsobinski assisted us in the field for part of the 1973 field season. Our data include graptolites collected from three localities by C. M. Tschanz in 1972. Dover's early mapping in the Pioneer Mountains was partially supported by grants from the National Science Foundation, Sigma Xi, the Geological Society of America, and Idaho Bureau of Mines and Geology. Helpful reviews by Michael Churkin, Jr., and S. W. Hobbs resulted in improvements in this report, but the authors accept sole responsibility for its content.

ORGANIZATION OF THE REPORT

This report is presented in two separate but interrelated parts. The first part, by Dover, R. J. Ross, Jr., and Berry, reviews previous concepts, presents lithologic and structural descriptions and faunal data bearing on the general geologic framework of the Ordovician-Silurian outcrop belt, and discusses problems of nomenclature, correlation, and facies interpretation of the Phi Kappa and Trail Creek Formations. The descriptive basis for the identification and discussion of problems is mainly the geologic mapping of Dover as simplified on plate 1 and in figure 1, and the map distribution of graptolite collections and zones identified by Berry and R. J. Ross, Jr., shown on plate 1. A brief summary of recommended stratigraphic changes is based on our stratigraphic and structural analysis.

The second part, by Berry, deals exclusively with the graptolite faunas, emphasizing assemblages not previously recorded or adequately described from these rocks. Late Early and early Middle Ordovician graptolites in two stratigraphic sections of the Phi Kappa Formation from which closely spaced collections were made are described systematically, illustrated, and discussed. Graptolite data for each collection are tabulated by USGS collection number in the section on "Description of Graptolite Collections."

Geology of the Ordovician-Silurian Outcrop Belt: Reevaluation of the Phi Kappa and Trail Creek Formations

By J. H. Dover, R. J. Ross, Jr., *and* W. B. N. Berry

THE PHI KAPPA FORMATION

STATEMENT OF THE PROBLEM

New mapping, combined with recent stratigraphic and paleontological work, indicates that a large proportion of the rocks previously included in the Ordovician Phi Kappa Formation differ lithologically from the black, graptolite-bearing carbonaceous argillite and shale succession with which the name Phi Kappa has become widely identified, and by which the formation is recognized in the field. Nearly all the nongraptolitic rocks can now be correlated with other lithostratigraphic units of various ages. These are mainly black massive argillite and black medium- to thick-bedded blocky argillite with abundant interbedded gritty quartzite that represent two thrust sequences of the Mississippian Copper Basin Formation; other nongraptolitic rocks are buff-weathering banded siliceous metasiltstone identical to the bulk of the original Trail Creek Formation and thin-bedded cherty to phyllitic argillite and yellow-brown dolomitic siltstone now included with an unnamed argillite and siltstone of Silurian and Devonian age. The stratigraphic problems arise from the fact that most sections of the Phi Kappa Formation previously reported were measured across major thrust faults and therefore include rocks of diverse lithologies and ages that are tectonically juxtaposed with the graptolitic rocks, as well as structural repetitions of the graptolitic section itself.

As the map distribution of the various rock units within the original Phi Kappa outcrop belt has become better known, so the need has increased for reappraising the Phi Kappa Formation as a viable lithostratigraphic unit. Consequently, we now propose to redefine the Phi Kappa Formation so as to include (1) only the part of the original Phi Kappa that consists of black, graptolite-bearing, carbonaceous, thin-bedded argillite and shale, which is now known to be a relatively thin succession representing a wide range of Ordovician time and which is present in numerous thrust imbrications within the original outcrop belt, and (2) lithologically identical graptolitic argillite of Silurian age that formerly was assigned to the overlying Trail Creek Formation. Together, these argillaceous beds constitute a distinctive, uniform, and regionally mappable lithostratigraphc unit. Only about 240 m of the Phi Kappa as redefined is present in the study area, compared with the 3,860 m originally estimated for the formation. Despite this drastic reduction in thickness and our exclusion from the formation of the rocks along Phi Kappa Creek from which the formational name originates, we recommend the name Phi Kappa be retained based on its widely accepted prior usage to denote the Ordovician graptolitic shale facies of central Idaho, and because the Phi Kappa Formation as redefined is present in thrust slices on Phi Kappa Mountain, at the head of Phi Kappa Creek.

REVIEW OF PREVIOUS CONCEPTS

The first Ordovician rocks discovered in the Pioneer Mountains were black shale containing graptolites of Early Ordovician (Beekmantown) age that crop out along the Trail Creek road (Blackwelder, 1913; loc. A in fig. 1; fig. 2). Younger Ordovician rocks were later

FIGURE 2.—Early Ordovician graptolite locality of Blackwelder (1913) on Trail Creek road approximately 1.6 km south of Trail Creek Summit (loc. A on pl. 1 and in fig. 1). The black, flaggy, and abundantly graptolitic argillite of the Phi Kappa Formation (Op) is tectonically overridden along a sharp thrust fault (toothed and dotted line) by an unusually thick section of the Basin Gulch Quartzite Member of the Phi Kappa (Opb).

mapped in the area by Westgate and C. P. Ross (1930), and these were named Phi Kappa Formation "* * * from exposures along Phi Kappa Creek" (p. 18). Westgate and C. P. Ross mapped their Phi Kappa Formation separately from the rocks of Blackwelder's locality because of the special scientific interest they attached to the rocks of Beekmantown age. The Phi Kappa was said to comprise two parts, a lower part consisting of generally black rusty-weathering flinty argillite, medium- to fine-grained sandstone or quartzite, and banded hornfels, and an upper part comprising interbedded dark laminated to thin-bedded shale containing graptolites, and yellow shaly sandstone. A combined thickness of more than 3,860 m (9,400 ft) was estimated for the Phi Kappa; and sections were measured (1) "on the ridge between Park Creek and the next creek north" (Westgate and C. P. Ross, 1930, p. 19), hereafter called the Park Creek ridge section (*B–B'* in fig. 1; frontispiece), (2) "on the ridge projecting from the west into the head of the valley northeast of Park Creek" (Westgate and C. P. Ross, 1930, p. 21), hereafter called the Little Fall Creek Springs section (location not precisely known but probably as shown by sec. *C–C'* in fig. 1), and (3) "on the north slope of the divide * * * at the head of Phi Kappa Creek" (Westgate and Ross, 1930, p. 22), hereafter called the Phi Kappa Mountain section (*D–D'* in fig. 1). Three main age groupings of graptolites identified by Edwin Kirk were thought to occur in the area: (1) Early Ordovician graptolites known only from Blackwelder's original locality on the Trail Creek road, (2) Late Ordovician graptolites known only from the beds immediately underlying the Trail Creek Formation as originally defined in a section on upper Trail Creek, and (3) Middle Ordovician graptolites which were said by Westgate and C. P. Ross to be widely distributed throughout the upper part of their Phi Kappa but which were considered to be rare and poorly preserved in the lower part.

Churkin (1963) described in more detail the lithic and faunal character of the Phi Kappa on the ridge between Park and Trail Creeks, hereafter called the Trail Creek Summit section (a composite of secs. *E–E"* and *E'"–E'* in fig. 1, and approximately equivalent to sec. *E–E'* on pl. 1 and in fig. 3). Although plate 1 of Westgate and C. P. Ross (1930) shows the Phi Kappa–Trail Creek belt to be cut by numerous faults, Churkin was the first to demonstrate that the deformational style of the belt is dominated by thrust faults that repeat section. He identified three thrust plates involving "two partly contemporaneous sequences differing in lithic detail" (1963, p. 1612–1613). The two most important of Churkin's thrust sequences are separated by a fault he designated the Park Creek thrust (pl. 1; fig. 3). His lower thrust plate is described as (p. 1612)

> * * * largely shale and argillite * * * or spotted slate depending on proximity to intrusions * * * interbedded with dark gray quartzite and * * * two prominent quartzitic members in its upper part. These upper members consist of whitish gray quartzose siltstone and very fine-grained quartzite very thinly interbedded and interlaminated with dark gray argillite, producing a banded rock.

A thickness of about 910 m (3,000 ft) was estimated for the lower thrust plate; rare and poorly preserved lower Caradocian graptolites were reported from "several argillaceous horizons" within it and were considered to "represent a stratigraphic span of more than 2,000 feet" (Churkin, 1963, p. 1612). The banded quartzites of the lower plate were thought to be offshore tongues of Kinnikinic Quartzite (Middle Ordovician). Churkin's lower plate Phi Kappa neither resembles nor is equivalent to any part of the lower Phi Kappa as it was understood by Westgate and C. P. Ross (1930), but rather it is encompassed within the upper part of their original Phi Kappa.

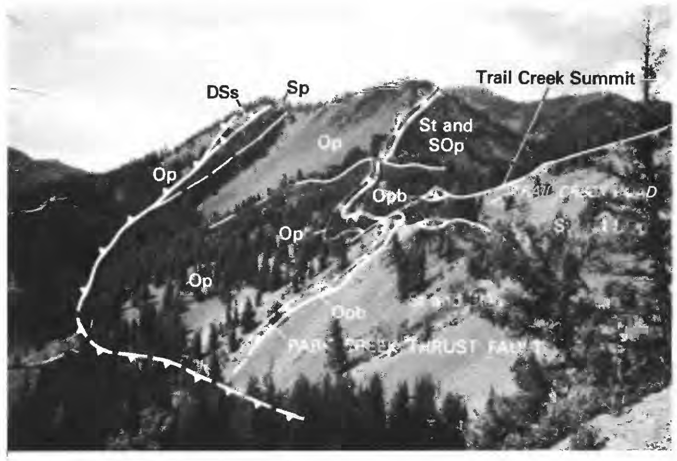

FIGURE 3.—Upper part of Trail Creek Summit section (*E–E'* on pl. 1 and in fig. 1) viewed from Trail Creek road approximately 0.8 km south of pass. Park Creek thrust separates upper- and lower-plate sequences of Churkin (1963). Thrust imbrications subsequently recognized within his lower plate sequence are shown on plate 1 but not on photograph. SOp, Silurian and Ordovician Phi Kappa Formation, undivided; Op, Ordovician part of Phi Kappa; Sp, Silurian part of Phi Kappa; Opb, Basin Creek Quartzite Member of Phi Kappa; St, Silurian Trail Creek Formation; DSs, siltstone in unnamed Devonian and Silurian unit. Contacts and faults dashed where approximately located; sawteeth on upper plate of thrust fault.

In contrast, Churkin reported that the Ordovician section above the Park Creek thrust which is only about 215 m (700 ft) thick, consists mainly of dark-gray shale and argillite with about 18 m (60 ft) of massive quartzite at the base and contains abundant well-preserved graptolites ranging in age from Arenigian through Ashgillian. This thin upper-plate Phi Kappa was thought to have been deposited west of the thicker lower-plate sequence. Churkin also suggested that the Lower Ordovician rocks of Blackwelder's locality on Trail Creek (loc. A on pl. 1 and in fig. 1) are a southern extension of the Arenigian part of his upper-plate sequence. Although new mapping shows these two sections to be in different thrust slices, Churkin was the first to demonstrate that Blackwelder's Beekmantown rocks are lithologically and faunally equivalent to parts of the Phi Kappa Formation and should be included with it. Ross and Berry (1963, p. 58) also included these Lower Ordovician strata with the Phi Kappa in their regional review of Ordovician graptolite occurrences. Though Churkin's 1963 paper has been an indispensible guide in subsequent studies, significant modifications are required by new mapping and paleontological data, particularly with respect to reported differences in thickness, lithology, graptolite fauna, and facies relations between his upper- and lower-plate sequences. Additional descriptions of graptolites from Churkin's upper-plate sequence were published by Carter (1972) and Carter and Churkin (1977). In this report we have avoided duplication of the work by Churkin and Carter on their upper-plate sequence inasmuch as their data on that part of the Trail Creek Summit section are consistent with our studies in other parts of the Phi Kappa–Trail Creek outcrop belt.

DISCUSSION

This discussion focuses on two problems concerning the Phi Kappa Formation that have developed as a result of new data bearing on the distribution of rock units within the Ordovician-Silurian outcrop belt: (1) use of the name Phi Kappa needs clarification because our proposed exclusions from the formation drastically reduce its thickness and restrict its outcrop area from that originally designated and because the rocks along Phi Kappa Creek from which the name originates are among those excluded, and (2) our new data indicate that basic stratigraphic concepts and structural models of the Phi Kappa need revision.

NOMENCLATURAL PROBLEM RESULTING FROM PROPOSED EXCLUSIONS

Carbonaceous and siliceous shale or argillite are the most common rock types within the Phi Kappa–Trail Creek outcrop belt originally designated. However, not all the argillaceous rocks belong to the same lithostratigraphic unit. Many of them differ from one another in composition, petrologic and bedding character, and age. In fact, at least seven different Paleozoic formations mapped in the northern Pioneer Mountains contain a significant component of black argillaceous material. Even so, these argillaceous rocks are not easily distinguished from one another, especially in isolated samples or discontinuous exposures. They are most readily separated by their associations with other diverse rock types or by stratigraphic position. Field experience shows that those argillaceous rocks that are actually Ordovician in age can usually be identified by careful mapping because they tend to be less siliceous (except along locally silicified shear zones) and more shaly or flaggy than other argillite in the area and because they generally contain identifiable graptolites despite the intensity of their deformation.

Graptolites were reported in all three principal sections of the Phi Kappa Formation measured by Westgate and C. P. Ross (1930, p. 21–22), but these occurrences were noted only in parts of the section. In the Little Fall Creek Springs (fig. 1, sec. *C–C′*) and the Phi Kappa Mountain (fig. 1, sec. *D–D′*) sections, the graptolites are restricted to black argillite and shale beds that were referred to the upper part of the formation. In both sections, nongraptolitic yellow shaly sandstone is associated with the graptolitic beds. In the Park Creek ridge section (fig. 1, sec. *B–B′*), Westgate and C. P. Ross reported graptolites only "* * * in the 400 feet of shale 1,680 feet above the base of the * * * section." Graptolites have now been recovered from other black argillite beds in the upper part of the Park Creek ridge section but not from the intervening banded hornfels units of their measured section. Because Westgate and C. P. Ross recognized that most of the rocks at Park Creek ridge are different from those in their other sections, they assigned the Park Creek ridge section to a stratigraphically lower part of their Phi Kappa. Rare and poorly preserved graptolites apparently were found in beds elsewhere in the area that were thought to correlate with their lower Phi Kappa. No graptolites were reported by Westgate and C. P. Ross (1930, p. 18) from the prominent argillite "exposures along Phi Kappa Creek" from which the formation name comes nor are fossils of any kind known now from this argillite. The rocks along Phi Kappa Creek apparently were correlated with the lower Phi Kappa at Park Creek ridge, about 3 km to the west, on the basis of a similarity in the argillite of the two areas; the rocks on Phi Kappa Creek have little or no similarity with the upper Phi Kappa as Westgate and C. P. Ross defined it.

The lower part of the Park Creek ridge section consists predominantly of interbedded medium- to thick-bedded black siliceous argillite and quartzite or gritty quartzite (also see lithologic descriptions in lower half of measured section of Westgate and C. P. Ross, 1930,

p. 19). The argillite and quartzite occur in nearly equal amounts. Both rock types are very resistant; the quartzite is composed of poorly sorted angular grains set in a partly recrystallized siliceous matrix. Graptolites have not been found in place in this lower clastic part of the Park Creek ridge section. However, USGS graptolite collection D2565 CO—from approximately 630 m north of point *E'* of section *E–E'* on plate 1—is from float of the structurally overlying graptolitic beds that moved downslope onto the argillite and quartzite succession. In its intimately intermixed coarse clastic content, bedding character, and lack of graptolites, the lower part of the Park Creek ridge section bears little similarity to the overlying graptolitic succession. A thin but intensely sheared and silicified zone just below our structurally lowest graptolite collection (D2566 CO) separates the graptolitic rocks in the upper part of the ridge from the more coarsely clastic succession in the lower part. New mapping now shows that the graptolitic beds occur in an imbricated thrust sheet that overrides the nongraptolitic clastic rocks along the silicified shear zone between the two sequences (pl. 1; frontispiece; figs. 1, 4). The nongraptolitic clastic rocks have been traced in the field into lithologically identical rocks in the upper of two allochthons of flysch deposits correlated with the Mississippian Copper Basin Formation. This allochthon, called the Glide Mountain thrust plate by Dover and others (1976) and in figure 1 of this report, consists of interbedded argillite, gritty sandstone or quartzite, and minor pebble conglomerate, all generally contorted, especially near its structural base. Direct paleontological dating still is not possible, but the presence of macerated plant fragments rules out an Ordovician age for the lower clastic part of the Park Creek ridge section.

The black siliceous argillite in the prominent cliffs along the lower part of Phi Kappa Creek also belongs to the Mississippian Copper Basin Formation. However, this argillite is not only devoid of graptolites, but also differs in several other important respects from all the rocks of the Park Creek ridge section. Although isolated samples of argillite from the two areas would be difficult to distinguish in some cases, the argillite along Phi Kappa Creek lacks sandstone in-terbeds and has a massive bedded character that gives extensive outcrops of this rock a bedding aspect easily distinguished from both sequences on Park Creek ridge. Also, some of the argillite on Phi Kappa Creek commonly contains sand-size grains of quartz and well-rounded granules of black argillite sparsely scattered through a well-sorted matrix, producing a rock that is quite distinct in sorting, grain-size distribution, and grain angularity from other argillaceous rocks. Similar

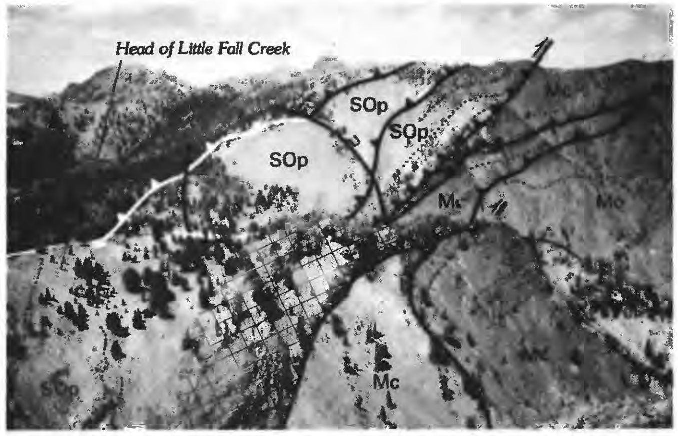

FIGURE 4.—Tectonic contact between imbricated allochthon of Phi Kappa Formation (SOp) and structurally underlying Mississippian clastic rocks of the Copper Basin Formation (Mc). View northeast across valley of Little Fall Creek. The Copper Basin beds are cut by several smaller thrust faults related to the main thrust. Zones of shearing are intensely silicified (pattern) in places. The Phi Kappa is overridden in turn by an unnamed Silurian and Devonian unit (DS) on the west. Thrust fault trace with closely spaced sawteeth separates the Phi Kappa and Copper Basin Formations; fault traces with wider spaced sawteeth mark subsidiary thrusts. Dotted line, bedding trace. Tei, Tertiary quartz monzonite stock.

rocks (Paull and others, 1972) occur in the Little Copper Formation of Paull and Gruber (1977), a unit in the southern Pioneer Mountains equivalent to the stratigraphically lowest part of the Copper Basin Formation. On the east side of Phi Kappa Creek, as at the Little Copper Creek locality examined by Paull and Gruber, the argillite is conformably overlain by medium- to thick-bedded silty, locally banded micritic limestone equivalent to the Drummond Mine Limestone of Paull, Wolbrink, Volkman, and Grover (1972). The limestone is no more than 122 m thick in exposures near the Phi Kappa mine, but its top is truncated there by the overriding Glide Mountain allochthon (Dover and others, 1976); the Drummond Mine yields a late Kinderhookian conodont fauna in structurally contiguous exposures less than 3 km away. In the Pioneer Mountains, the Drummond Mine Limestone is known only in the lower of the two allochthons of Copper Basin Formation—the Copper Basin thrust plate of Dover and others (1976).

In summary, the name Phi Kappa comes from exposures along Phi Kappa Creek of massive argillite that can now be assigned with confidence to the Copper Basin plate of the Mississippian Copper Basin Formation. This lithostratigraphic unit differs from all the rocks in the lower Phi Kappa of Westgate and C. P. Ross (1930) at the Park Creek ridge section, but it was not previously distinguished from them. The interbedded argillite and gritty quartzite succession that occupies the lower 650 m of the Park Creek ridge section is also assigned to the Mississippian Copper Basin Formation, but to a coarser clastic and carbonate-free facies restricted to the structurally higher Glide Mountain thrust plate. Furthermore, the Park Creek ridge section was originally measured across at least two major thrust faults, including not only the thrust separating the graptolite-bearing rocks in the upper part of the ridge from the Copper Basin strata in the lower part, but also one that repeats section in the graptolitic sequence as well. Reassignment of the banded siliceous metasiltstone beds tectonically imbricated with the graptolitic sequences to the Trail Creek Formation is discussed elsewhere in this report. The age of the Phi Kappa ranges from Arenigian (Early Ordovician) into Wenlockian (Middle Silurian).

Other rocks of the original outcrop belt now excluded from the Phi Kappa Formation are mainly unfossiliferous black, thin-bedded, siliceous or cherty, locally phyllitic argillite, and associated tan-weathering, limy to dolomitic, laminated siltstone. These are provisionally assigned to an unnamed Silurian and Devonian unit (Dover and others, 1976). The siliceous argillite resembles parts of the Milligen Formation (Devonian), which crops out in an extensive belt about 4 km west of Trail Creek Summit. A klippe of the calcareous siltstone caps Park Creek ridge northwest of section *B–B'* (frontispiece), and the same siltstone is tectonically imbricated with two thrust slices of graptolitic Phi Kappa argillite and shale on Phi Kappa Mountain (pl. 1; fig. 1, sec. *D–D'*). The unnamed Silurian and Devonian unit also occurs as structural imbrications in the Little Fall Creek Springs section of Westgate and C. P. Ross (1930; fig. 1, sec. *C–C'*) and elsewhere within the Phi Kappa–Trail Creek outcrop belt. Other aspects of some of these strata are discussed in a later section of this report (p. 16).

PROBLEMS WITH PREVIOUS STRATIGRAPHIC AND STRUCTURAL CONCEPTS RAISED BY NEW DATA

Churkin's (1963) identification of important thrust faults in the Trail Creek Summit section was a critical key to subsequent mapping of the Phi Kappa belt. However, in attempting to extend these faults into other parts of the belt, it became evident that the structure was far more complicated than Churkin's work indicated. The degree of complexity is indicated by our restudy of the lower part of Churkin's section at Trail Creek Summit, which shows his so-called lower-plate sequence to comprise at least four imbricate thrust slices (pl. 1, sec. *E–E'*, slices I–IV) of rocks lithologically and faunally similar to those of his upper-plate sequence. Thrust slice III contains in itself a continuous shale and argillite succession about 213 m thick encompassing Ordovician graptolite zones 8 through 15.[2] This particular shale interval corresponds to the middle argillite unit of Churkin's lower-plate sequence, which clearly is not restricted to the lower Caradocian as his figure 2 indicates (Churkin, 1963, p. 1613). The shale is mostly black and carbonaceous but is limy and contains a few thin limestone interbeds in the Middle Ordovician part of the section. The lower part of the shale section is sheared and poorly exposed and is converted to spotted slate near an intrusive contact. A cherty, possibly silicified zone about 2.5 m thick is present in the upper part of the unit. Above zone 15 (USGS collns. D2594 CO and D2595 CO), the upper 9 m of shale and its contact with the overlying banded metasiltstone unit (the upper of Churkin's two quartzitic members) are poorly exposed in this thrust slice because of shearing, and some argillite may be cut out. However, 4 km to the northwest at the section of the Trail Creek Formation originally described by Westgate and C. P. Ross (1930, p. 23–24; pl. 1, loc. F; fig. 5), the same contact is conformable. There Upper Ordovician beds (Zone of *D. complanatus ornatus*) grade over about 15 m through Lower and Middle Silurian argillite into banded siliceous metasiltstone lithologically identical with the banded units in Churkin's lower-plate sequence at Trail Creek Summit. Though they are not directly dated by fossils, both banded quartzitic units in the imbricated lower part of the Trail Creek Summit section lie 9–30 m above Upper Ordovician beds, a stratigraphic interval comparable with that at the Trail Creek section and compatible with a Silurian age. A third unit of banded siliceous metasiltstone, one not shown on Churkin's section but occurring at the base (east end) of the Trail Creek Summit ridge section, is thrust bounded and represents another structural slice of the same Silurian metasiltstone beds (pl. 1, sec. *E–E'*, slice I).

We conclude that the lithic and faunal differences cited by Churkin (1963) to distinguish his two structural sequences were based on incomplete data and reflect the presence of unrecognized thrust faults that repeat section in his lower plate. As a result, the inferences on facies differences and major facies telescoping within the Phi Kappa–Trail Creek outcrop belt to which his data led are invalid. Instead, the graptolitic shale and argillite contained in imbricate thrust

[2]The Ordovician graptolite zones used in this report are those of Berry (1960, 1976). Zone names and correlations with the zones of Elles and Wood (1901–14) are given in table 4. The classification used in this report for Silurian graptolite zones is that of Elles and Wood (1901–14).

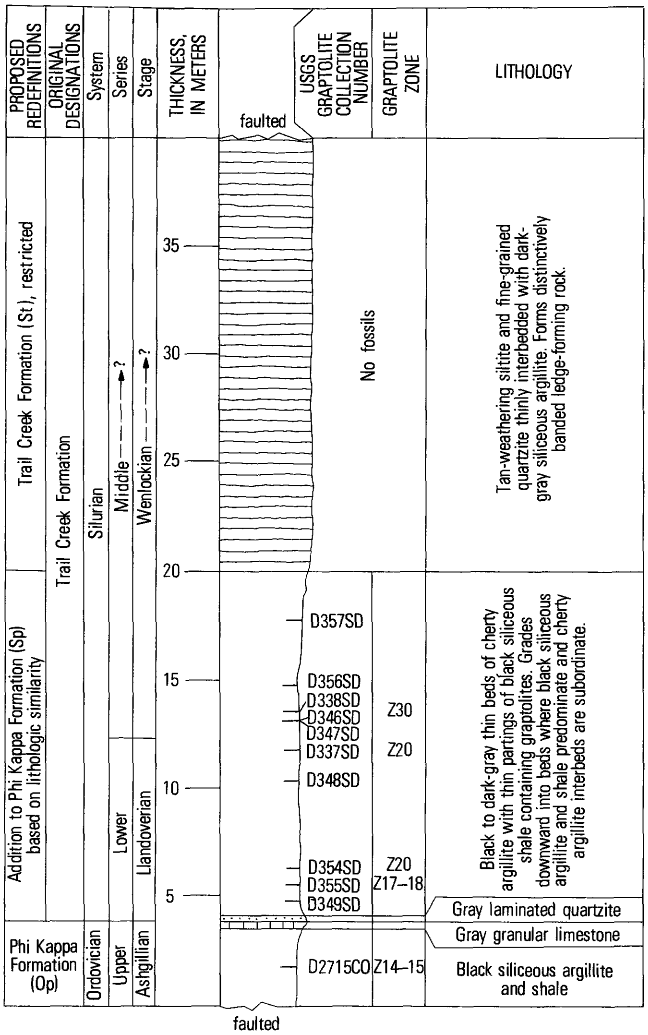

FIGURE 5.—Columnar section of the principal reference section of the Trail Creek Formation (pl. 1, loc. F), showing graptolite collection localities and zonal assignments. Ordovician graptolite zones from Berry (1960), Silurian zones from Elles and Wood (1901–14). West side of Trail Creek near where fork in road crosses creek. Base of section is at road level, approximate altitude 2,445 m (8,020 ft). Universal Transverse Mercator grid, zone 11: E. 717,010 m, N. 4,859,650 m. Rock Roll Canyon 7½-minute quadrangle, Idaho.

slices throughout the belt are all similar in lithology, thickness, graptolite fauna, and age. Although the Park Creek thrust fault separating Churkin's upper- and lower-plate sequences is a valid thrust that repeats section, it is no more significant than any of several other thrusts that imbricate the Ordovician-Silurian rocks, including at least two in his lower-plate sequence. Some thrust slices probably developed from the upright limbs of large, nearly isoclinal, eastward-overturned folds which were concurrently and (or) subsequently refolded and cut by high-angle faults of small displacement (pl. 1; fig. 1). No overturned sections have been identified, but additional graptolite sampling may show some to be present. Further modifications in the structural interpretation of this complex area may be required as additional data become available. Although the style and frequency of structural repetition clearly indicates tectonic shortening of at least several kilometers distributed within the Phi Kappa–Trail Creek outcrop belt (pl. 1; frontispiece; fig. 1), there are no major lithofacies or faunal differences in adjacent structural plates within the belt that require major tectonic telescoping of widely separated parts of the original shale basin.

THE PHI KAPPA FORMATION, REDEFINED

Graptolite-bearing shale and argillite beds predominate in the Phi Kappa Formation as revised here. Most of these rocks were included within the Phi Kappa Formation as originally defined, but some were previously assigned to the overlying Trail Creek Formation. The argillaceous beds are predominantly black and carbonaceous, but locally they are intensely silicified. Rusty weathering is common where the rock is altered or contact metamorphosed. Shaly parting is irregularly preserved because of deformation, silicification, and recrystallization. Subordinate limy shale in the middle (Caradocian) part of the unit weathers light gray. The only other calcareous rocks in the Phi Kappa are a few micritic limestone beds less than half a meter thick scattered through the formation. Quartzite also occurs sparsely as interbeds generally less than 10 cm thick, particularly in the lower half of the formation, but a bed of gray, generally fine-grained, locally pebbly quartzite containing well-sorted and well-rounded grains is prominent at the base. The lithologically distinctive basal quartzite grades through an interval of 1–2 m into the overlying black graptolitic argillite beds typical of the bulk of the formation, and locally it forms detached tectonic lenses within zones of intensely sheared argillite (pl. 1, sec. *G–G′*). The basal quartzite is included with the Phi Kappa following the usage of Churkin (1963). However, it is mapped separately on plate 1, and in recognition of its distinctive lithology, it is here named the Basin Gulch Quartzite Member of the Phi Kappa Formation. The name comes from exposures just northwest of the junction of Basin Gulch and Trail Creek, near the east edge of the Rock Roll Canyon quadrangle, which compose the type locality. The Basin Gulch Member has limited areal extent but is exposed most continuously in the uppermost thrust slice of the Phi Kappa mapped in the area (pl. 1).

Essentially the same section of the revised Phi Kappa Formation is structurally repeated in numerous imbricate thrust slices within the outcrop belt previously designated for the formation. The only apparent difference in lithology between Churkin's upper plate sequence at Summit Pass and the Phi Kappa in thrust slices throughout the rest of the outcrop belt is that limy shale is not reported in the Caradocian part of his upper plate strata, which may contain more quartzite than is present in most other thrust slices.

The base of the Phi Kappa Formation as redefined is a tectonic contact throughout the region examined. Most thrust slices also include banded metasiltstone beds of the gradationally overlying Trail Creek Formation, as restricted in this report. The gradation occurs through an interval of about 15 m. The upper contact of the Phi Kappa is drawn at the place where resistant buff-weathering Trail Creek strata predominate over black, generally graptolitic Phi Kappa beds. Typically, the contact approximately coincides with the break in slope between a cliff supported by the Trail Creek and a receding slope cut on the less resistant Phi Kappa below the cliff. No more than about 240 m of the revised Phi Kappa has been measured in any thrust slice, including about 17 m of Silurian strata at the top, but this total thickness is a minimum because the lower contact (and commonly both contacts) is invariably a fault. The thickness of the Basin Gulch Quartzite Member varies from place to place because of deformation. It is generally 60 m thick or less but may be slightly thicker in its southernmost exposure along the Trail Creek road (pl. 1).

Except for the relative abundances of certain species of the same faunal assemblage, graptolite faunas found in different thrust slices of the Phi Kappa Formation are closely similar. The graptolites obtained represent all Ordovician graptolite zones from Berry's zones 2–4 through 15 (Churkin, 1974; Carter and Churkin, 1977), as well as at least parts of the Early and Middle Silurian. Graptolites in most collections indicate a late Early to Late Ordovician age for the beds from which they come. In the present study, only collections D2501 CO, D2519 CO, D2520 CO, and D2540 CO include graptolites of an Ordovician age older than zone 6. These are poorly preserved but represent an age in the range of zones 2–4. R. J. Ross, Jr., and Berry (1963) reported that part of USGS colln. 1367 SD contains graptolites suggestive of Berry's zone 5. The map distribution of our collections indicates that unbroken stratigraphic successions containing graptolites of late Early (zone 6) through latest Ordovician (zone 15) age are present in at least two different thrust slices. These are in thrust slice III and Churkin's upper plate sequence in the Trail Creek Summit section (pl. 1, sec. *E–E'*). Nowhere have Lower Ordovician strata containing graptolites older than zone 6 been shown to be in stratigraphic continuity with beds of late Early to Late Ordovician (zone 6 or younger) age (for example, Little Fall Creek section, pl. 1, sec. *G–G'*). Carbonaceous shale beds of latest Ordovician age appear to grade stratigraphically into superjacent strata of similar lithology in which the Silurian graptolites are present. Known occurrences of graptolitic Silurian shale beds are still rare in the Phi Kappa–Trail Creek outcrop belt. The three presently documented are at the original section of the Trail Creek (Westgate and C. P. Ross, 1930, p. 19–20), in Churkin's upper-plate sequence at Trail Creek Summit (1963, p. 1615; this report, pl. 1, sec. *E–E'*), and at the mouth of Cold Canyon (USGS colln. D2539 CO, pl. 1), where exposures are poor and stratigraphic and structural relations are uncertain. Additional occurrences may be found by sampling the argillite interval immediately below the banded metasiltstone in the various thrust slices. However, shearing concentrated at the argillite-metasiltstone contact during deformation may obscure these critical beds in some places. Closer attention to Silurian strata may reveal graptolites that more precisely document the nature of the Ordovician-Silurian boundary within the Phi Kappa Formation and expand the age range of the Silurian beds.

The so-called upper plate sequence of the Trail Creek Summit section (Churkin, 1963; Carter and Churkin, 1977) supplemented by the Little Fall Creek section of Berry (second part of this report) are here considered reference sections of the Phi Kappa Formation as revised. The first shows a maximum range of age and is the more thoroughly sampled and described, but the Middle Ordovician part of the Little Fall Creek section may be more complete and complements the Trail Creek Summit section, possibly because of minor structural complications in the upper plate at Trail Creek Summit.

REGIONAL CORRELATION

Black graptolitic Ordovician shale and argillite similar to that of the Phi Kappa Formation occurs at several localities in central Idaho north of the present map area, but at all of these it was assigned to other formations by previous workers. The shale was mapped as Ramshorn Slate and thought to be Early Ordovician in age by C. P. Ross (1937) along a 4.8-km segment of East Pass Creek just north of the Meridian Peak quadrangle (fig. 6, loc. 1), and in an area of several

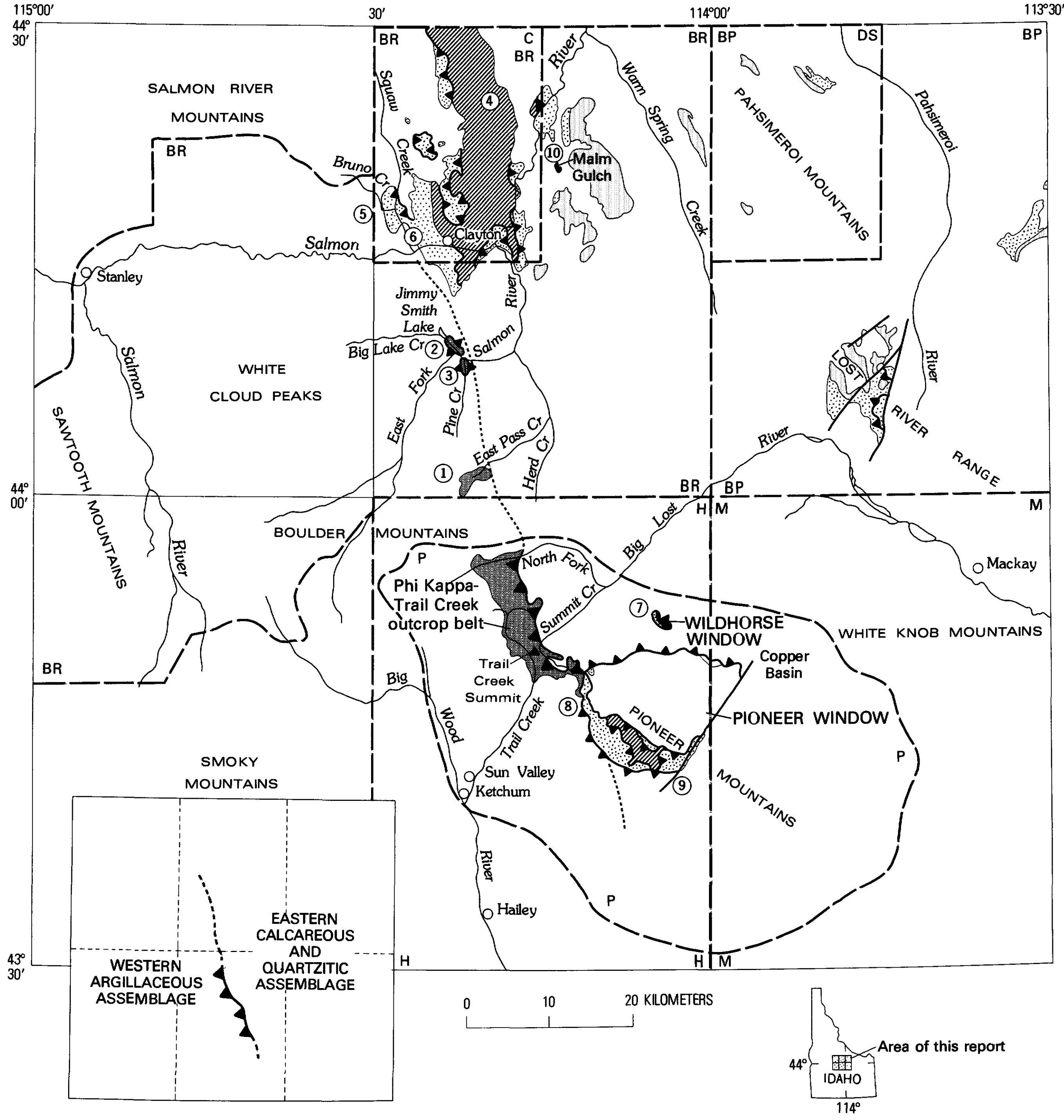

FIGURE 6.—Map showing distribution of Ordovician and Silurian rocks in central Idaho. Index to geologic mapping: P, Dover (in press); C, Hobbs, Hayes, and McIntyre (1975); DS, Mapel and others (1965); M, Nelson and Ross (1937); BR, Ross (1937); BP, Ross (1947); H, Westgate and Ross (1930).

square kilometers along lower Big Lake Creek (south of Jimmy Smith Lake) and lower Pine Creek, near their junctions with the East Fork of the Salmon River, 40 km north of Trail Creek Summit (fig. 6, locs. 2, 3). None of these areas has been mapped in detail since the original work was done.

Brief reconnaissance in the East Pass Creek area by R. J. Ross, Jr. and S. W. Hobbs in 1974, and by Dover

EXPLANATION

EASTERN CALCAREOUS AND QUARTZITIC ASSEMBLAGE

SILURIAN ROCKS—Mainly Laketown Dolomite

ROBERTS MOUNTAINS FORMATION (DEVONIAN AND SILURIAN)—Mapped only in Wildhorse window and at Malm Gulch

ORDOVICIAN ROCKS—Includes Clayton Mine Quartzite, Ella Dolomite, Kinnikinic Quartzite, and Saturday Mountain Formation in Clayton quadrangle (Hobbs, Hayes, and McIntyre, 1975), correlative rocks in areas east and southeast of Clayton, and metamorphosed equivalents (East Fork Formation and upper unit of Hyndman Formation) in Pioneer window (Dover, in press)

METASEDIMENTARY ROCKS (ORDOVICIAN? OR OLDER)—Includes Ramshorn Slate, Bayhorse Dolomite, and Garden Creek Phyllite in Clayton quadrangle (Hobbs and others, 1975), and lower three units of Hyndman Formation in Pioneer window (Dover, in press)

WESTERN ARGILLACEOUS ASSEMBLAGE

PHI KAPPA AND TRAIL CREEK FORMATIONS (SILURIAN AND ORDOVICIAN)—Includes some structural imbrications of younger Paleozoic rocks

CONTACT

HIGH-ANGLE FAULT

THRUST FAULT

SOLE THRUST OF ALLOCHTHONOUS SEQUENCES OF LOWER PALEOZOIC ARGILLACEOUS ROCKS (WESTERN FACIES)—Dotted where concealed

⑤ LOCALITY CITED IN TEXT

and R. J. Ross, Jr., in 1976, confirmed that both lithologically and faunally the shale is Phi Kappa and that it and an unnamed Silurian and Devonian unit resembling the one in the Pioneer Mountains are involved in a style of imbricate thrusting identical to that of the main Phi Kappa-Trail Creek belt to the south.

Likewise, brief examination of the lower Big Lake Creek-Pine Creek area by Dover and Hobbs in 1975 found black, graptolite-bearing shale like the Phi Kappa there as well, rather than slate as the Ramshorn correlation implies. Here, the Phi Kappa is restricted to the lower 35 m or less of valley sides. Intensely deformed but nonslaty, dominantly siliceous rocks resembling those provisionally correlated with the unnamed Silurian and Devonian unit of the Pioneer Mountains are exposed higher on valley sides and appear to have overridden the Ordovician shale along a nearly horizontal thrust fault; although graptolites have not been reported from these upper plate siliceous beds, these strata also were included with the Ramshorn by C. P. Ross (1937). From this reconnaissance, we conclude that all the rocks assigned to the Ramshorn in the East Pass Creek and Big Lake Creek-Pine Creek areas differ lithologically and structurally from the faintly laminated Ramshorn Slate of the type locality in the Clayton 15-minute quadrangle, 65 km north of Trail Creek Summit (fig. 6, loc. 4); and the small percentage of those rocks that can be dated as Ordovician are similar in lithology and graptolite occurrence to the Phi Kappa Formation. Equivalence of the Phi Kappa and the true Ramshorn has never been demonstrated, and therefore the original dating of the Ramshorn as Lower Ordovician based on fossils at East Pass, Big Lake, and Pine Creeks is invalid. Nevertheless, the Ramshorn still is tentatively assigned to the Ordovician(?) by Hobbs, Hayes, and McIntyre (1975) on the basis of stratigraphic relations near Bayhorse, Idaho.

At another locality, near the junction of Bruno and Squaw Creeks in the Clayton 15-minute quadrangle, 55 km north of Trail Creek Summit (fig. 6, loc. 5), carbonaceous graptolitic shale is included in the lower part of the Saturday Mountain Formation (C. P. Ross, 1937; Hobbs and others, 1975). Here, near its type locality, the Saturday Mountain consists mainly of platy limestone and cherty dolomite with several interbeds of mostly calcareous shale; thrust faults obscure both the upper and lower contacts (Hobbs and others, 1975). In areas to the east and southeast, the Saturday Mountain contains little or no shale except at its sheared base (C. P. Ross, 1947; Mapel and others, 1965). R. J. Ross, Jr., questions whether the graptolite-bearing shale at Bruno Creek is stratigraphically interbedded in a facies of the Saturday Mountain that is transitional between the argillaceous Phi Kappa assemblage to the west and the nearly shale-free carbonate facies of the Saturday Mountain to the east, or alternatively, whether the shale may be a slice of allochthonous Phi Kappa that was tectonically emplaced.

The predominance of argillaceous rocks in the relatively thin Phi Kappa Formation contrasts markedly with other Ordovician strata in central Idaho. Rocks largely of Middle Ordovician age but aggregating more than 1,000 m in thickness comprise the Ella Dolomite, Kinnikinic Quartzite, and the Saturday Mountain Formation described by C. P. Ross (1937), Hobbs, Hayes, and R. J. Ross, Jr., (1968), and Hobbs, Hayes, and McIntyre (1975) near Clayton (fig. 6, loc. 6). The equivalent Middle Ordovician beds of the Phi Kappa Formation are predominantly black carbonaceous shale but include subordinate gray limy shale. The age of the Kinnikinic Quartzite as restricted by Hobbs, Hayes, and R. J. Ross, Jr., (1968) in the Clayton area is bracketed between early Middle and late Middle Ordovician. No comparable sandstone or quartzite of similar age is recognized in the sections of the Phi Kappa that are now known to be most continuous and complete (pl. 1, secs. *E-E'*, *G-G'*), though thin quartzite interbeds occur in the lower part of the revised Phi Kappa. (See measured section of Carter and Churkin (1977).) The quartzitic members mentioned by Churkin (1963) in his lower plate sequence are probably Silurian and can no longer be considered as possible Kinnikinic equivalents. However, the Basin

Gulch Quartzite Member of the revised Phi Kappa, which is Arenigian or older, resembles the Kinnikinic in color, purity, sorting, and size and rounding of grains, though it differs in being thinner and locally conglomeratic. If correlative, the two quartzites transgress time. Caution is required in interpreting the anomalous association of the Basin Gulch Quartzite Member with shale containing Middle Ordovician (Caradocian) graptolites at two localities on our map—one near the meadows above Trail Creek Falls and the other on the divide between the heads of Trail and Little Fall Creeks. Both of these localities are near the sheared base of a structural plate where tectonic juxtaposition of the units occurred.

The Ordovician Ella-Kinnikinic-Saturday Mountain succession near Clayton represents a dominantly calcareous and quartzitic shelf assemblage that extends southward from the Bayhorse region and Lost River Range into southeastern Idaho. The westernmost exposures of similar rocks known in southern Idaho are on the northwest side of the low hills south of Twin Falls (P. L. Williams, oral commun., 1976). Rocks equivalent to the Saturday Mountain Formation and correlated with the Hanson Creek Formation of Nevada also are exposed in the Wildhorse structural window of the northeastern Pioneer Mountains (fig. 6, loc. 7), less than 11 km east of the Phi Kappa outcrop belt (Dover and R. J. Ross, Jr., 1975). Unlike the calcareous Saturday Mountain elsewhere, graptolites are present in the dark cherty dolomite of the Wildhorse window.

At the head of the Right Fork of Kane Creek, at the southeast corner of the present map area (fig. 6, loc. 8), graptolitic Phi Kappa shale representing Berry's zone 7 (USGS colln. D2551 CO) tectonically overrides intensely deformed, medium- to high-grade metamorphic equivalents of the Ella-Kinnikinic-Saturday Mountain succession of the Clayton area (pl. 1; fig. 1; Dover and others, 1976). Correlation of the metasedimentary rocks with the section near Clayton is based on similarities in the sequence and thicknesses of individual formations, on striking similarities in lithologic details and sedimentary structures, and on the recent discovery in the uppermost metasedimentary unit (at an outcrop on Cabin Gulch, about 16 km southeast of Kane Creek—loc. 9 in fig. 6) of late Middle Ordovician trilobite fragments characteristic of the Saturday Mountain Formation. The following genera identified by R. J. Ross, Jr., are present at Cabin Gulch:

Cryptolithoides sp.
Ceraurinid, probably *Ceraurinella* sp.
Possibly *Anataphrus* sp.

THE TRAIL CREEK FORMATION

STATEMENT OF THE PROBLEM

The Trail Creek Formation is composed mainly of buff-weathering, dark and light banded, siliceous metasiltstone at the section on upper Trail Creek where it was first described. Black graptolitic argillite occurs in the lower part of the formation as originally defined. The graptolitic argillite, which represents less than 10 percent of the formation, has been emphasized in the literature because of the importance of its monograptid fauna to age dating. The Trail Creek problem stems from the fact that (1) the basal graptolitic argillite beds are lithologically similar to the conformably underlying Phi Kappa Formation and cannot be distinguished from it in the field without fossils, and (2) buff-weathering banded rocks lithologically identical to those that predominate in the original Trail Creek section were misassigned to the Phi Kappa Formation elsewhere in the Ordovician-Silurian outcrop belt. We have already recommended inclusion of the basal graptolitic argillite beds of the original Trail Creek with the revised Phi Kappa. We here restrict the Trail Creek Formation to the buff-weathering, banded, siliceous metasiltstone that constitutes the bulk of the formation as originally defined, and which is a distinctive and readily identified lithostratigraphic unit throughout the mapped area.

REVIEW OF PREVIOUS CONCEPTS

The Trail Creek Formation was first described by Westgate and C. P. Ross as "* * * a series of siliceous argillite and thin-bedded quartzitic sandstone" (1930, p. 23). The formation was recognized only on the west side of upper Trail Creek (sec. *F-F'* on pl. 1 and in fig. 1), where about 152 m (500 ft) of strata was reported. Silurian graptolites of early Wenlockian age identified by Edwin Kirk were recovered from black carbonaceous argillite restricted to "the basal 60 feet of the formation" (p. 24). The basal argillite of the original Trail Creek is lithologically similar to the conformably underlying Ordovician beds of the Phi Kappa Formation. Westgate and C. P. Ross distinguished the Trail Creek by its monograptid fauna from the Phi Kappa. Thus, the boundary between the two formations as originally defined was biostratigraphic.

In his study of the Trail Creek Summit section, Churkin (1963) discovered Silurian graptolites in the upper 14 m (47 ft) of shale in his upper plate sequence. There, as at the original Trail Creek section, the

Silurian beds are concordant with lithologically similar underlying beds containing Late Ordovician graptolites. However, in Churkin's upper plate sequence, the graptolitic Silurian beds are overlain by calcareous siltstone rather than banded siliceous rocks as at the original Trail Creek section.

DISCUSSION

Although Westgate and C. P. Ross (1930) reported the general location of their original Trail Creek section, R. J. Ross, Jr., and others have been unsuccessful in recent years in recovering the locality from which their Silurian graptolite collections were made. Rediscovery of his locality came quite by accident in 1973 as a result of a sample picked up at random from float by a geologic field assistant. The slab of graptolitic argillite was first thought to be part of the Ordovician Phi Kappa Formation, but R. J. Ross, Jr., found it to contain monograptids. The locality from which it came lies just above road level on the west side of the upper part of Trail Creek about 60 m north of where a branch of the road crosses the creek (sec. *F–F'* on pl. 1 and in fig. 1). This locality is almost certainly the same one described by Westgate, C. P. Ross, and Edwin Kirk. The graptolites occur in argillite that gradationally underlies buff-weathering, dark and light banded, siliceous metasiltstone, just as reported by Westgate and C. P. Ross. However, the stratigraphic position of the Silurian graptolites below the metasiltstone section was unexpected because lithologically identical metasiltstone elsewhere in the Ordovician-Silurian outcrop belt was considered to be Ordovician (the banded hornfels units of Westgate and C. P. Ross, 1930, p. 19–20; and the banded quartzite members of Churkin, 1963, fig. 2, p. 1613). Rediscovery of the original Silurian locality was the key factor that led us to question the Ordovician assignment of the banded metasiltstone in occurrences throughout the Phi Kappa–Trail Creek outcrop belt and ultimately to reassign it to the Trail Creek Formation.

Many factors probably entered into the long-delayed recognition and resolution of the Trail Creek problem. If Westgate and C. P. Ross (1930) considered what now seems to be an obvious lithologic correlation between the main body of their Trail Creek Formation and their banded Phi Kappa hornfels beds, the correlation may have been abandoned because of the structural complications that such an interpretation would have introduced into their reconnaissance map. Once the banded hornfels elsewhere in the outcrop belt was assigned to the Phi Kappa, the Silurian age of the same rocks in their Trail Creek section could not be inferred from subsequent geologic maps, and the Silurian graptolite locality of the original section was lost. The difficulty of finding the locality by blind sampling is compounded by the fact that the Silurian beds are thin and lithologically indistinguishable from the Phi Kappa. Churkin's misassignment of his lower plate banded quartzite members to the Phi Kappa perpetuated the problem—a problem that could be recognized only by detailed graptolite sampling in the intervening argillite units of his lower plate sequence, or by study of the section on Trail Creek itself.

Graptolites recollected from the basal beds of the original Trail Creek section range from Early to Middle Silurian in age. Ten collections within a stratigraphic interval of about 15 m are tabulated in figure 5. Uppermost Ordovician beds of zone 15 (USGS colln. D2715 CO) occur no more than 3.6 m stratigraphically below our lowest Silurian collection. The intervening strata are lithologically similar to the beds above and below, except for the presence of a granular limestone bed 20 cm thick and an overlying quartzite bed 13 cm thick.

Our reexamination of graptolite zonations in the lower part of the Trail Creek Summit section (pl. 1, sec. *E–E'*) lends paleontological support for a Silurian age of the banded metasiltstone beds there and for their correlation with the original Trail Creek. Although Silurian graptolites have not yet been recognized in any of the thrust slices below the Park Creek thrust, the banded metasiltstone in slice II lies approximately 30 m stratigraphically above Upper Ordovician beds (zones 13–14) and in slice III are about 10 m above sheared uppermost Ordovician beds (zone 15). In both thrust slices, the banded metasiltstone is separated from Upper Ordovician strata by a stratigraphic interval comparable with the equivalent interval at the original section of the Trail Creek.

TRAIL CREEK FORMATION, RESTRICTED

The Trail Creek Formation is here restricted to the buff-weathering, dark and light banded, thinly interbedded siliceous argillite, metasiltstone, and very fine grained quartzite which constitutes the main body of the original Trail Creek Formation at the locality described by Westgate and C. P. Ross (1930). Dark layers are composed of black argillite that generally is more siliceous and extensively recrystallized than argillite in the Phi Kappa. Light layers have less disseminated carbon than dark layers, have a grain size ranging from silt to very fine sand, and contain as much as 50 percent of anhedral tremolite in randomly oriented aggregates. Banding generally is on a scale of 1–5 cm per band, but locally it is irregular.

The restricted Trail Creek Formation occurs in stratigraphic sequence with the revised Phi Kappa Formation in numerous thrust slices within the mapped area (pl. 1). The Trail Creek Formation originally described by Westgate and C. P. Ross (1930) (sec. *F–F'* on pl. 1 and in fig. 1) is here designated the principal reference section of the revised formation. Other excellent exposures of the revised Trail Creek are those given by Westgate and C. P. Ross for their banded hornfels units and by Churkin for his banded quartzite members. Reassignment of these rocks from the Phi Kappa to the Trail Creek Formation extends significantly the area occupied by Silurian rocks in the Phi Kappa–Trail Creek outcrop belt.

The lower contact of the restricted Trail Creek Formation at the principal reference section is gradational through an interval of a few meters with the Silurian argillite beds now included in the revised Phi Kappa. The contact generally coincides with the change in weathering color and break in slope between the buff cliff-forming Trail Creek and the black and less resistant Phi Kappa as described in an earlier section. The top of the Trail Creek is faulted throughout the region mapped, and therefore the thickness of the formation in all thrust slices is a minimum. The nearly 135 m (440 ft) reported by Westgate and C. P. Ross (1930) at the principal reference section is unreliable because of additional high-angle fault complications there. No more than about 100 m of the restricted Trail Creek is present in other thrust slices, but this is a minimum thickness.

Fossils have not been recovered in the Trail Creek Formation as restricted. The presence of graptolites as young as Wenlockian about 2 m below the base of the Trail Creek as drawn at the principal reference section indicates that the formation is Wenlockian (Middle Silurian) or younger in age (fig. 5). A minimum age cannot be determined at this time.

REGIONAL CORRELATION

C. P. Ross (1937, p. 17, USGS colln. 2463 SD) reported Silurian graptolites from rocks of uncertain lithology at East Pass Creek just north of the map area (loc. 1 in fig. 6). These collections have not been duplicated in the subsequent reconnaissance into the area and that occurrence remains unconfirmed.

The name Trail Creek was applied by C. P. Ross (1937) to monograptid-bearing gray platy limestone near Malm Gulch, about 16 km northeast of Clayton in the Lone Pine Peak 7½-minute quadrangle (loc. 10 in fig. 6). These rocks bear no lithologic similarity to any part of the Trail Creek Formation as originally defined or as here restricted at the principal reference section. Both lithologically and faunally, the rocks at Malm Gulch are identical to strata assigned to the Roberts Mountains Formation in the Wildhorse window of the northeastern Pioneer Mountains (loc. 7 in fig. 6) by Dover and R. J. Ross, Jr. (1975). There, the Roberts Mountains gradationally overlies dark cherty dolomite of the Hanson Creek Formation (Saturday Mountain equivalent). The Malm Gulch and Wildhorse window Silurian sections represent an Early to Middle Silurian part of the calcareous shelf of central Idaho that is tectonically overridden by the argillaceous and siliceous Phi Kappa–Trail Creek assemblage on the west.

UNNAMED SILURIAN AND DEVONIAN CALCAREOUS SILTSTONE

In light of the Silurian rocks already discussed, another lithologic unit that merits separate consideration here is the calcareous siltstone reported by Churkin (1963, p. 1615) to overlie the Silurian shale in his upper plate sequence at Summit Pass. This siltstone is easily distinguished from the banded, siliceous, noncalcareous metasiltstone of the Trail Creek. We correlate the calcareous siltstone in Churkin's section with lithologically similar beds that cap west-facing dip slopes on Phi Kappa Mountain, on the ridge south of upper Summit Creek, and on the divide between Little Fall and upper Trail Creeks. At these places, the siltstone is a distinctive tan- to orange-brown-weathering, slabby, limy to dolomitic, cliff-forming bed at least 60 m thick. Bedding surfaces contain abundant worm trails, but no diagnostic fossils are known from the siltstone. It originally was included with the Phi Kappa Formation (Westgate and C. P. Ross, 1930, pl. 1) and later was assigned to the Wood River Formation by Dover (1969). Most recently, it is provisionally assigned to an unnamed unit of Silurian and Devonian rocks (Dover and others, 1976). The provisional age is based on the identification of Late Silurian (Ludlovian) conodonts in two samples of "silty limestone" (C. A. Sandberg, written commun., 1975) from within a part of the unnamed Devonian-Silurian unit where argillite predominates, a short distance northwest of the present map area. Farther north, at East Pass Creek, samples from a thin interbed of bioclastic limestone in identical calcarecous siltstone yielded conodonts of probable late Ludlovian but possibly earliest Devonian age (Anita Harris, written commun., 1975). A Late Silurian age is therefore inferred for the calcareous siltstone. Along with associated lithologies (black siliceous argillite of pl. 1) in the unnamed Silurian and Devonian unit, the calcareous siltstone is tectonically interlayered with the Phi Kappa and Trail Creek Formations within the area mapped, and similar rocks in structurally complex thrust sheets override the Phi Kappa–Trail Creek outcrop belt on the west (Dover and others, 1976). The calcareous siltstone in the Trail Creek Summit section is presently mapped as a thin tectonic sliver of the unit sandwiched between Churkin's upper plate sequence and the next overlying thrust slice of Phi Kappa (pl. 1).

The lithology of the calcareous siltstone resembles most closely orange- or yellow-brown-weathering dolomitic siltstone beds described by Sandberg, Hall, Batchelder, and Axelson (1975) in the Milligen Formation (Devonian), and most of its associated lithic components in the unnamed unit of Silurian and Devonian rocks also are typical of the Milligen. The lithic content and provisional age of the calcareous siltstone suggest that it may occupy a stratigraphic position between the Trail Creek and Milligen Formations, as restricted. However, the age and stratigraphic relations of these beds are still too poorly delineated to warrant formal designation.

The Graptolite Fauna

By W. B. N. Berry

In this part of the report, attention is focused mainly on two closely sampled stratigraphic sequences, here called the Trail Creek Summit and Little Fall Creek sections, each representing a different thrust slice. The Trail Creek Summit section, shown in our Trail Creek Summit structure section (*E–E'*, of pl. 1 and fig. 1), forms the cliffs south of Park Creek, just west of the campground, and corresponds to the middle argillite unit of Churkin's lower plate sequence (1963, p. 1613). The Little Fall Creek section, collected in detail by Dover, Hobbs, and R. J. Ross, Jr. in 1973, and again by Dover and Berry in 1974, shown in the upper part of our Little Fall Creek structure section (*G–G'*, of pl. 1 and fig. 1), is along a small northeast-flowing tributary of Little Fall Creek near but apparently not coincident with a section of the same name mentioned briefly by Churkin (1963) and by Carter and Churkin (1977). Both the Trail Creek Summit and Little Fall Creek sections are in the northeast part of the Rock Roll Canyon 7½-minute quadrangle.

Of the 116 graptolite collections studied from the map area, nearly a third are from the Trail Creek Summit and Little Fall Creek sections. Within these sections, collections are spaced closely enough to document the stratigraphic ranges of certain graptolite species or associations of species more precisely than has been possible elsewhere in North America. Emphasis here is on late Early and early Middle Ordovician isograptid, pseudisograptid, and associated taxa that are new to North America or that are not treated fully in previous studies. These taxa are discussed and described systematically in the following portions of this report. Also included, because of their bearing on the story of late Early to early Middle Ordovician graptolite development in North America, are two collections (USGS collns. D2596 CO and D2597 CO; table 1) from the base of the thrust slice immediately overlying Churkin's Park Creek thrust (his upper plate sequence; pl. 1 and fig. 1).

In addition, Late Ordovician faunas representing Berry's zones 13 through 15 are present in collections from the upper 30 m (100 ft) of the Trail Creek Summit section. The stratigraphically lowest of the Upper Ordovician beds contains *Climacograptus spiniferus* Ruedemann (USGS colln. D2591 CO). The fauna of superjacent beds includes large orthograptids of the type *O. quadrimucronatus* and *O. calcaratus* (USGS colln. D2592 CO). The youngest Ordovician fauna is characterized by *Dicellograptus ornatus minor* Toghill, *Climacograptus supernus* Elles and Wood, and orthograptids of the type *O. truncatus* (USGS collns. D2594 CO and D2595 CO). In the upper part of Churkin's upper plate sequence, *Climacograptus bicornis* (J. Hall) is present in a collection of ours (USGS colln. D2558 CO) that occurs about 15 m (50 ft) stratigraphically below Late Ordovician faunas reported by Carter and Churkin (1977) that are equivalent to those of our Trail Creek Summit section. Recognition of Late Ordovician faunas in the Trail Creek Summit section was critical to our interpretation of structure in the Phi Kappa–Trail Creek outcrop belt. However, late Middle and Late Ordovician taxa are not included in the systematic descriptions because the forms represented in our collections and their succession are consistent with faunas already described by Carter and Churkin (1977) from the Phi Kappa, and by R. J. Ross, Jr., and Berry (1963) from the Great Basin.

THE LATE EARLY–EARLY MIDDLE ORDOVICIAN FAUNAS

The stratigraphically lowest and, therefore, the oldest graptolites obtained in stratigraphic sections in the area mapped are in collections D2596 CO and D2597 CO (table 1; pl. 1). Collection D2596 CO includes several specimens of *Didymograptus pro-*

TABLE 1.—*Graptolite faunas and zone assignments of collections from base of Trial Creek Summit section, reference section for the Phi Kappa Formation (upper plate sequence of Churkin, 1973; sec. E-E′ of our pl. 1), Pioneer Mountains, Idaho*

[Base of thrust slice is at base of Basin Gulch Quartzite Member. Collection D2596 CO was made through approximately 0.6 m of stratigraphic section begining at the first argillite layer above the quartzite. Collection D2597 CO came from about 2.1 m stratigraphically above the quartzite. a, abundant; c, common; r, rare; leadersd (--), absent]

Zone	*Didymograptus protobifidus*	*Didymograptus bifidus–Isograptus victoriae*
Zone of Berry (1960, 1976; also of Barnes and others, 1976	6	7–8
USGS Colln. No.	D2596 CO	D2597 CO
Didymograptus protobifidus Elles	a	--
Phyllograptus angustifolius J. Hall	c	--
Tetragraptus sp.	c	--
Didymograptus sp.	c	--
Didymograptus cf. *D. nicholsoni planus* Elles and Wood	--	c
Amplexograptus? sp.	--	r
Isograptus victoriae lunatus Harris	--	c
Isograptus victoriae victoriae Harris	--	c

tobifidus Elles in association with *Phyllograptus angustifolius* J. Hall. *D. protobifidus* occurs through about 0.6 m of stratigraphic section. The stratigraphically lowest occurrence of it is about 10 cm above the Basin Gulch Quartzite Member of the Phi Kappa. A single specimen that may be interpreted as either an immature *D. bifidus* (J. Hall) or a transient from *D. protobifidus* to *D. bifidus* (fig. 2 of pl. 2) occurs with the stratigraphically highest *D. protobifidus* specimens found.

Stratigraphically superjacent layers (USGS colln. D2597 CO; table 1 and pl. 1) contain abundant specimens of *Didymograptus* cf. *D. nicholsoni planus* Elles and Wood, in association with *Isograptus victoriae lunatus* Harris, *I. victoriae victoriae* Harris, and a biserial scandent rhabdosome that may be an amplexograptid. The occurrence of this association millimeters stratigraphically above that of *D. protobifidus* with a possible *D. protobifidus-D. bifidus* transient suggests that a fauna in which isograptids of the *I. victoriae* group are prominent may be, at least partially, coeval with a fauna in which *D. bifidus* is common (table 4). That the two faunas may not be wholly coeval is indicated by the stratigraphic occurrence of the *D. bifidus* fauna in beds below that of isograptids of the *I. victoriae* group in the Marathon region, Texas (Berry, 1960) and Spitsbergen, Norway (Fortey, 1976). *I. victoriae lunatus* has been recorded with *D. bifidus* in eastern New York (Ruedemann, 1947). *I. victoriae lunatus* ranges from beds below to beds containing *I. victoriae victoriae* in Australia and New Zealand (Thomas, 1960; Cooper, 1973). It occurs with *I. victoriae victoriae* as well as stratigraphically below it in the Marathon region (Berry, 1960).

Glyptograptus austrodentatus americanus Bulman is abundant in the lower part of the Little Fall Creek section (USGS collns. D2693a, c, d, g CO; table 2). That subspecies is joined by *Cardiograptus morsus* Harris and Keble; possible *Oncograptus upsilon* T. S. Hall, *Glossograptus hincksii* (Hopkinson), and *Isograptus caduceus australis* Cooper; *Isograptus caduceus imitatus* Harris, and possible *Pseudobryograptus incertus* (Harris and Thomas) (USGS colln. D2693g CO). A single specimen of probable *I. victoriae lunatus* (USGS colln. D26936 CO) was found within the section typified by many specimens of *G. austrodentatus americanus* (table 2).

Specimens similar to *Didymograptus hemicyclus* Harris (USGS colln. D2693d CO), a species previously cited only from Australia and New Zealand (Thomas, 1960; Cooper, 1973) and Kazakstan (Tsai, 1974), occurs in the lower part of the Little Fall Creek section. This species occurs in a somewhat similar association in Kazakstan (Tsai, 1974), but it is found in beds stratigraphically below those bearing *D. protobifidus* in the Australian and New Zealand sequences (Thomas, 1960; Berry, 1966; Cooper, 1973).

Glyptograptus austrodentatus americanus occurs with a few specimens that are closely similar to *G. austrodentatus austrodentatus* Harris and Keble (USGS collns. D2693a, c, g CO). The latter subspecies characterizes the lower part of the Australian-New Zealand Middle Ordovician Darriwil Stage (Thomas, 1960). That the geographic ranges of the two subspecies apparently overlapped in what is now central Idaho is further indicated by the presence of several rhabdosomes having characters suggestive of affinities with both subspecies. Features of the proximal region of these rhabdosomes are more similar to the Australian subspecies, but rhabdosome width is more like that of the North American subspecies.

Diplograptus decoratus multus Ross and Berry (USGS collns. D2693h, j CO) is common in beds stratigraphically superjacent to those bearing primarily *G. austrodentatus*. Most of the dichograptids disappear with *G. austrodentatus*. The beds bearing *D. decoratus multus* also contain *Holmograptus spinosus* (Ruedemann), *Climacograptus*, *Paraglossograptus*?, and possible *Pseudoclimacograptus*. Dichograptids, though present, are markedly less conspicuous in the strata bearing *D. decoratus multus* and in all layers subjacent to them.

TABLE 2.—*Graptolite faunas and zone assignments of collections from Little Fall Creek section, reference section for the Phi Kappa Formation sec.*G–G′ *on pl. 1), Pioneer Mountains, Idaho*

[Collection D2693a CO is at base of sequence and collection numbers are arranged in stratigraphic order above it. r, rare; ?r, rare and identification uncertain: c, common; a, abundant; leaders (--), absent]

Zone of Berry (1960, 1976; also of Barnes and others, 1976	*Isograptus victoriae* 8							*Paraglossograptus etheridgei* 9			*Glyptograptus* cf. *teretiusculus* 10	
USGS Colln. No.	D2693a CO	D2693f CO	D2693e CO	D2693b CO	D2693d CO	D2693c CO	D2693g CO	D2693h CO	D2693i CO	D2693j CO	D2693k CO	D2693l CO
Oncograptus upsilon T.S. hall	r	----	----	----	----	----	----	----	----	----	----	----
Cardiograptus morsus Harris and Keble	c	----	----	----	----	----	----	----	c	----	----	----
Glyptograptus austrodentatus austrodentatus Harris and Keble	*c*	*r*	----	----	----	*c*	*c*	----	----	----	----	----
Glyptograptus austrodentatus americanus Bulman	a	----	----	----	a	a	a	----	----	----	----	----
Glossograptus hincksii (Hopkinson)	?r	----	----	----	----	----	c	c	----	----	----	----
Isograptus caduceus australis Cooper	a	----	----	----	c	c	----	----	----	----	---	----
Didymograptus sp.	r	----	----	----	----	----	----	----	----	----	----	----
Phyllograptus sp. (cf. *P. nobilis* Harris and Keble	r	----	----	----	----	----	----	r	?r	----	----	----
Glossograptus acanthus Elles and Wood	----	?r	----	----	----	----	----	----	----	----	----	----
Isograptus forcipiformis (Ruedemann)	----	----	?r	----	----	----	?r	r	----	----	----	----
Isograptus victoriae lunatus Harris	----	----	----	r	----	----	----	----	----	----	----	----
Isograptus caduceus imitatus Harris	----	----	----	----	c	c	c	----	----	----	----	----
Didymograptus cf. *D. hemicyclus* Harris	----	----	----	----	r	----	----	----	----	----	----	----
Tetragraptus sp.	----	----	----	----	r	----	----	----	r	----	----	----
Cryptograptus schaferi Lapworth	----	----	----	----	----	c	?r	c	c	----	?r	----
Dichograptus sp.	----	----	----	----	----	r	r	----	----	----	----	----
Tetragraptus amii Lapworth	----	----	----	----	----	r	r	----	----	----	----	----
Pseudisograptus dumosus (Harris)	----	----	----	----	----	----	?r	----	----	----	----	----
Pseudobryograptus sp. (cf. *P. incertus* (Harris and Thomas))	----	----	----	----	----	----	c	----	----	----	----	----
Diplograptus decoratus multus Ross and Berry	----	----	----	----	----	----	----	c	----	c	a	a
Holmograptus spinosus (Ruedemann)	----	----	----	----	----	----	----	r	----	----	----	----
Pseudoclimacograptus ? sp.	----	----	----	----	----	----	----	r	----	----	----	----
Paraglossograptus ? sp.	----	----	----	----	----	----	----	----	r	----	----	----
Climacograptus sp. (? *C. riddellensis* Harris)	----	----	----	----	----	----	----	----	r	----	----	r
Cryptograptus sp. (cf. *C. tricornis* (Caruthers))	----	----	----	----	----	----	----	----	c	----	----	----
Didymograptus sp. (cf. *D. cuspidatus* Ruedemann)	----	----	----	----	----	----	----	c	?r	----	----	----
Glyptograptus cf. *G. euglyphus* Lapworth	----	----	----	----	----	----	----	----	----	----	?r	c
Lasiograptus sp.	----	----	----	----	----	----	----	----	----	----	----	r

Stratigraphically higher, *Glyptograptus* cf. *G. euglyphus* Lapworth (USGS colln. D26931 CO) appears in the succession to join *D. decoratus multus; Holmograptus spinosus* and other dichograptids are not present. The association of *G.* cf. *G. euglyphus* and *D. decoratus multus* is probably coeval with that of *Glyptograptus* cf. *G. teretiusculus* (Hisinger) and *Pseudoclimacograptus marathonensis* Clarkson in the Marathon region, Texas. Coeval faunas from Nevada (Ross and Berry, 1963) are relatively similar to that from the Little Fall Creek section.

Isolated collections from the Trail Creek Summit section (USGS collns. D2516a, b CO; table 3) include pseudisograptids not previously cited from North America (*P. dumosus* (Harris) and specimens described herein as pseudisograptids) in association with *Pseudisograptus manubriatus* (T. S. Hall), *Pseudobryograptus, Glossograptus, Isograptus*

TABLE 3.—*Graptolite faunas and zone assignments of collections from near base of thrust slice III at Trail Creek Summit (sec.* E–E′ *on pl. 1), Pioneer Mountains, Idaho*

[c, common; r, rare; leaders (--), absent]

Zone of Berry (1960, 1976; also of Barnes and others, 1976)	*Isograptus victoriae* 8		
USGS Colln. No.	D2516a CO	D2516b CO	D2516c CO
Cardiograptus morsus Harris and *Keble*	r	---	---
Cryptograptus sp.	r	---	---
Glossograptus hincksii (Hopkinson)	c	---	---
Isograptus cadudeous australis Cooper	c	---	---
Isograptus caduceous imitatus (Harris)	c	---	---
Pseudisograptus dumosus (Harris)	r	c	---
Pseudisograptus manubriatus (T. S. Hall)	r	r	---
pseudisograptid	c	---	---
Pseudobryograptus incertus (Harris and Thomas?)	c	r	---
Tetragraptus amii (Lapworth)	r	---	---
Glossograptus sp.	---	r	---
Tetragraptus sp.	---	c	---
Didymograptus sp. (cf. *D. cuspidatus* Ruedemann)	---	---	r
Glossograptus cf. *G. acanthus* Elles and Wood)	---	---	c
Isograptus victoriae victoriae Harris	---	---	c
Phyllograptus sp.	---	---	r

caduceus australis Cooper, and *Isograptus imitatus* Harris. Neither *Diplograptus* nor *Glyptograptus* were found in the Trail Creek Summit section, although faunas cited herein probably are coeval with those from the lower part of the Little Fall Creek section.

ECOLOGICAL POSSIBILITIES

Comparison of the fauna from the lower part of the Little Fall Creek section (USGS collns. D2693a, c, d, g CO) with approximately coeval faunas in collections from the Trail Creek Summit section (USGS collns. D2516a, b, c CO) shows the two faunas to be somewhat dissimilar. Pseudisograptids are a striking element of the Trail Creek Summit fauna (table 3); whereas *Glyptograptus austrodentatus americanus* Bulman and *Glyptograptus austrodentatus austrodentatus* Harris and Keble are the most prominent taxa in the Little Fall Creek fauna (table 2). Associated species of *Glossograptus, Isograptus,* and *Pseudobryograptus* occur in relatively similar abundances in both sequences.

The strata exposed in both the Little Fall Creek and Trail Creek Summit sections have been sampled intensively enough by different collectors at several different times to suggest that faunal differences are not a result of incomplete sampling, small collections, or other sampling bias. Multiple collections, although small in some cases, of the same stratigraphic interval have yielded the same taxa as those indicated in table 3—and in similar proportions. This apparent reproducibility suggests that the faunas recovered in each sequence are representative of those present and that the differences cited are real.

The Ordovician and (or) Silurian succession within each thrust slice is relatively coherent and shows little internal deformation. Both the lithologic similarity of the strata exposed in the various thrust slices and their structural style and configuration indicate that thrusting of sufficient magnitude to have produced major facies telescoping between adjacent slices is not likely. Possibly, random preservation of particular taxa accounts for the faunal variations observed. However, the graptolites involved appear to have had periderms of about similar durability. This durability and their mode of life lead me to conclude that whatever graptolites lived in each area probably were preserved in the same area.

An alternative explanation is that slightly different environmental conditions may have persisted in the waters over the depositional areas represented by the Trail Creek Summit and Little Fall Creek sections, the two water masses supporting slightly different yet coeval faunas. The possibility that different planktonic faunas may live in adjacent water masses having different hydrographical conditions is consistent with the differences among planktonic faunas described in the north Pacific Ocean by Fager and McGowan (1963) and the North Sea by Fraser (1965). Indeed, the degree of difference between the probably coeval faunas from the Little Fall Creek and Trail Creek Summit sections is markedly less than is the difference between planktonic faunas living in adjacent water masses in the North Sea. The difference in the two fossil faunas is consistent with a possible difference between two planktonic faunas, the fossil remains of which are, in effect, time averaged by their preservation in a sedimentary-rock succession.

ZOOGEOGRAPHIC DISTRIBUTION

The central Idaho early Middle Ordovician taxa described herein include the pseudisograptids *P. dumosus* and pseudisograptid?, *Isograptus caduceus imitatus, Didymograptus* cf. *D. hemicyclus,* and *Glyptograptus austrodentatus austrodentatus,* which are known from Australian and New Zealand Ordovician faunas but have not been recorded previously from North America. The presence of these taxa as well as of *Pseudisograptus manubriatus, Isograptus caduceus australis, Oncograptus upsilon,* and *Cardiograptus morsus,* species that are relatively well known from Australian-New Zealand Ordovician graptolite faunas but have been cited rarely from North American faunas, indicates clearly the zoogeographic relationship of the Idaho fauna with the Pacific Faunal Region of the Middle Ordovician. The isograptids, pseudisograptids, *Oncograptus, Cardiograptus,* and the members of the *Glyptograptus austrodentatus* group are characteristic members of the Pacific Faunal Region assemblage (Berry, 1967; Skevington, 1973).

Tsai (1974) described many isograptids and other taxa characteristic of the Pacific Faunal Region from Kazakstan. The associations of species and the sequence of associations are similar to those in central Idaho.

BIOSTRATIGRAPHIC DISTRIBUTION

The presence of isograptids and pseudisograptids seldom recorded or previously unrecorded from elsewhere in North America increases the number of Middle Ordovician graptolite taxa known in North America. Their distribution in stratigraphic sequences, although not diagnostic for zonal subdivision, is consistent with the general succession of late Early into early Middle Ordovician graptolite faunas recognized elsewhere in North America (Berry, 1960; Ross and Berry, 1963; Jackson and Lenz, 1962; Jackson and others, 1965). The general pattern of disappearance of many dichograptids and appearance of *Glyptograptus* similar to *G. euglyphus* in occurrence with *Diplograptus decoratus* supports the boundary between the zones designated 9 (*Paraglossograptus etheridgei*) and 10 (*Glyptograptus* cf. *G. teretiusculus* or *Glyptograptus euglyphus*) proposed by Berry (1960; 1968). That zonal boundary interval has been recorded rarely in North American graptolitic successions. Its presence in central Idaho is a valuable addition to knowledge of North American Ordovician graptolite zonation.

The presence of *Cardiograptus morsus* and isograptids of several types with *Glyptograptus austrodentatus* in central Idaho is consistent with similar associations in the Marathon region, Texas. It is also consistent with the implication, derived from analysis not only of the Ordovician graptolite succession in the Marathon region but also of that in the Yukon and Nevada, that the zonal sequence used successfully in Victoria, Australia (Thomas, 1960), may not be carried to North America. *G. austrodentatus* is used in Australia, for example, to distinguish beds stratigraphically above those bearing *C. morsus* and most isograptids and pseudisograptids. It occurs with *C. morsus, Oncograptus,* and diverse isograptids in western North America.

The occurrence of *Isograptus victoriae lunatus* and *I. victoriae victoriae* in layers stratigraphically superjacent to layers bearing *Didymograptus protobifidus* in central Idaho is evidence that the *Didymograptus bifidus*-bearing beds of the Marathon region, which there overlie those bearing *D. protobifidus,* are partly coeval with strata characterized by the presence of smaller members of the *Isograptus victoriae* group. The presence of that fauna, said to typify the *D. bifidus* zone in the Marathon region (primarily *D. bifidus* and *D. artus*) (Berry, 1960), appears to be related more to ecologic conditions than to temporal change in and evolutionary development of graptolite faunas. The evidence presently available suggests that, locally, a *D. bifidus* zone may be recognizable in North American areas east of the Great Basin and Yukon.

CONCLUSIONS

The central Idaho faunas discussed herein include taxa that indicate relatively closer zoogeographic affinities with Australian and New Zealand Ordovician graptolites than Ordovician graptolite faunas previously recorded from North America. (See also Carter and Churkin, 1977). The presence of certain similar taxa and coeval associations in Kazakstan (Tsai, 1974) suggests that both Kazakstan and western North America lay within the Ordovician graptolite Pacific Faunal Region and that oceanic current circulation swept both areas as well as Australia and New Zealand. These areas may all have bordered an Ordovician Pacific Ocean.

The presence of a *Didymograptus protobifidus*-zone fauna that is succeeded closely stratigraphically by one in which *Isograptus victoriae victoriae* is present is consistent with an interpretation suggested by Bergstroem and Cooper (1973) that the North American *D. bifidus* and *Isograptus* zonal faunas are partly coeval. The occurrence of two faunas that are coeval but somewhat dissimilar suggests that the distribution of Ordovician planktic graptolite faunas were influenced by ecologic conditions, just as are many modern oceanic planktic faunas.

SYSTEMATIC DESCRIPTIONS

Classification and nomenclature used herein is essentially that recommended by Bulman (1970) in his revision of the Graptolite section, Part V of the "Treatise on Invertebrate Paleontology." Isograptid nomenclature and systematic classification follow Beavis (1972) and Cooper (1973).

Many specimens in the collections are incomplete, and nearly all are relatively highly compressed. The descriptions are based primarily upon the most complete, most nearly mature, least deformed specimens.

Class GRAPTOLITHINA
Order GRAPTOLOIDEA
Suborder DIDYMOGRAPTINA Lapworth, 1880, emend, Bulman, 1970
Family DICHOGRAPTIDAE Lapworth, 1873

Dichograptids are typified by their simple tubular thecae that commonly are straight or slightly curved.

Section Goniograpti
Genus PSEUDOBRYOGRAPTUS Mu, 1957

Members of the Genus *Pseudobryograptus* are characterized by pendent rhabdosomes in which branching is dichotomous and but two or three orders of branches or stripes are developed.

Pseudobryograptus incertus (Harris and Thomas, 1935)?
Plate 2, figure 7

The rhabdosomes are either fragmentary or a group of contorted stipes. The sicula is about 1.5 mm long and 0.1 to 0.15 mm wide at its aperture. Each of the initial two stipes diverge from it at a 45° to 50° angle. The first two stipes are 1.3–1.5 mm long and about 0.4 to 0.5 mm wide. They branch by dichotomy to give rise to two stipes that are as much as 14 or 15 mm long in the specimens at hand. These second-order stipes diverge from each other at about a 90° angle initially, but they curve to become essentially subparallel. The second-order stipes are 0.4 to 0.6 mm wide across thecal apertures in their proximal parts, and they are 0.8 to 1.0 mm wide across thecal apertures in their distal parts.

Thecae number about five in 5 mm. Only thecae on the second-order stipes may be examined. Thecae on the distal part of the second-order stipes are dichograptid in aspect and have a flaring tubular shape. Thecal overlap is one-fourth to one-fifth. The ventral thecal walls are curved. Thecal walls near their join with the apertural margin form a 55° to 68° angle with the stipe axis. The inner part of the ventral thecal walls form a 15° to 25° angle with the stipe axis. Apertural margins are slightly concave and are approximately normal to the stipe axis. Thecal apertural margins are denticulate.

Figured specimens.—USNM 241111, 241142b(?).

Occurrence.—USGS collns. D2516a CO, D2516b CO.

Discussion.—Thecal shape indicates that these specimens are dichograptids. Stipes of only first and second order appear to be present, because the stipes that appear to be most clearly second-order stipes do not branch. All branching seen in the specimens is dichotomous. The general arrangement of the stipes in the most complete specimens available suggests that the rhabdosomes were essentially pendent forms. General rhabdosome shape suggests that the rhabdosomes may be assigned to the Genus *Pseudobryograptus* Mu. Thecal shape and thecal characteristics as well as stipe width suggest that the specimens might be referred to *P. incertus* (Harris and Thomas, 1935). The Idaho specimens are closely similar to typical Australian specimens of *P. incertus* in all characters that may be observed.

Section Dichograpti

Members of the Section Dichograpti typically possess eight or fewer stipes. Stipes of only three orders are present, and those of the first two orders are relatively short.

Genus DICHOGRAPTUS Salter, 1863
Dichograptus sp.
Plate 3, figure 6

First-order stipes are 1.1 to 1.3 mm long and 0.1 to 0.2 mm wide. The funicle ranges from 2.2 to 2.5 mm long. The second-order stipes are 1.4 to 1.5 mm long and 0.1 to 0.2 mm wide. The second-order stipes enclose a 125° to 140° angle between them. The third-order stipes are as much as 22 mm long. They are 0.3 to 0.4 mm wide across the aperture of the first theca on them. They become their maximum width of 0.5 to 0.9 mm at the aperture of the second or third theca and maintain that width for the remainder of their extent. The initial parts of the third-order stipes enclose a 100° to 120° angle between them, but the distal parts flex inward toward each other.

Thecae on the third-order stipes number eight to nine in 10 mm. They overlap approximately one-fourth or slightly less. The proximal parts of their free ventral walls form a 10° to 20° angle with the stipe axis, but the distal parts of the free ventral walls curve markedly to form a 50° to 60° angle with the stipe axis. The apertural margins are normal to the stipe axis. The marked curvature of the distal parts of the free ventral thecal walls and the orientation of the apertural margins combine to give the apertures a moderately denticulate appearance.

The sicula appears to have been small. It was not seen clearly because it had been crushed in the specimens available.

Figured specimen.—USNM 241112.

Occurrence.—USGS collns. D2504b CO, D2590 CO, D2693c CO, D2693g CO.

Discussion.—The Idaho specimens appear to differ from described species of *Dichograptus.* They resemble *D. octobrachiatus* in number of stipes and lengths of the first- and second-order stipes, but stipe width, particularly of the third-order stipes, is less than in *D. octobrachiatus.* The Idaho specimens bear some resemblance to *D. maccoyi* Harris and Thomas (1940); but thecae in the Idaho specimens are more curved, and the stipes of the Idaho specimens are thinner than in *D. maccoyi.*

Section Tetragrapti
Genus PHYLLOGRAPTUS Hall, 1858

Phyllograptid rhabdosomes have four scandent stipes that are second-order in origin and are arrayed essentially back-to-back, so that each rhabdosome is + shaped in cross section.

Phyllograptus sp.
Plate 4, figure 4

The specimens are incomplete, but they may be related to *P. nobilis* because thecal curvature is similar. The rhabdosomes appear to be relatively broad compared with their lengths. A relatively complete specimen is at least 12 mm long and 9.5 mm wide.

Thecal spacing in the medial part of the rhabdosome is 11 to 12 in 10 mm. The inner parts of thecae in the medial part of the rhabdosome are inclined to the rhabdosome axis at a 45° to 55° angle. The thecae curve to become essentially horizontal for that part of their length near the outer margin of the rhabdosome. Thecal curvature continues beyond the rhabdosome margin in most thecae such that the outer parts of most thecae are normal to the rhabdosome axis or declined at angles of as much as 10° from normal to the rhabdosome axis. Apertural margins are concave. The curving free ventral wall and curved apertural margins combine to form a distinct apertural flange at the sides of the rhabdosome.

Figured specimen.—USNM 241113.

Occurrence.—USGS collns. D2239 CO, D2516 CO, D2516b CO, D2537 CO, D2590 CO, D2693a CO, D2693i CO.

Discussion.—Thecal form in the Idaho specimens is closely similar to that in Victorian specimens of *P. nobilis* and *P.* cf. *P. nobilis* (Berry, 1966, pl. 44, figs. 6–9, pl. 45, fig. 2). The Idaho specimens are broader than *P. nobilis.*

Section Didymograpti

Members of the Section Didymograpti are typified by rhabdosomes composed of two stipes. Stipe arrangements range from two separate and pendent to reclined stipes to those that have biserial form.

Genus DIDYMOGRAPTUS M'Coy in Sedgwick and M'Coy, 1851

The two stipes in the Genus *Didymograptus* are pendent to reclined.

Didymograptus cf. D. hemicyclus Harris, 1933
Plate 3, figure 1

The rhabdosomes have a reclined shape in which the stipes diverge initially from the sicula at a 100° to 105° angle. The stipes curve upwards by the third thecal pair. The first pair of thecae are approximately horizontal. Their positions give the broadly semicircular-shaped rhabdosome a short interval in which no curvature is present. The stipes are 5.1 to 5.7 mm long. They are 1.0 to 1.1 mm wide at the apertures of $Th1^1$ and 1^2 and they are 1.4 to 1.5 mm wide at the apertures of the second thecal pair. The stipes are that width for the remainder of their extent. The width indicated includes the denticulate apertural lip.

The thecae number four in 3 mm. They overlap about one-third their length. The ventral walls are markedly curved. Their proximal parts form a 25° to 30° angle with the stipe axis, and their distal parts form a 75° to 85° angle with the stipe axis. The apertural margins are straight and form a 10° to 22° angle with a line normal to the stipe axis. The ventral walls curve most markedly near the join with the aperture, giving a sharp denticulate appearance to the apertural lip. The denticulate part of the apertural lips is commonly broken, but the most complete are 0.3 mm long.

The sicula is about 1.2 mm long and 0.5 mm wide at its aperture. It has a 0.4-mm-long virgella. The first theca originates relatively high on the metasicula. The proximal part of the ventral wall of the second theca is about level with the sicula aperture.

Figured specimen.—USNM 241114.

Occurrences.—USGS colln. D2693d CO.

Discussion.—The Idaho material described is closely similar to typical *Didymograptus hemicyclus* from Victoria, Australia, described and illustrated by Harris (1933) and Berry (1966), in rhabdosome size and shape, thecal shape and spacing, and sicular characteristics. The Idaho specimens appear to have been more fully compressed than any of the Victoria specimens examined by Berry (1966), which may be the reason that stipe width in the Idaho specimens is 0.2 to 0.3 mm greater than it is in the Victoria specimens. In addition to the difference in stipe width, the denticulate part of the apertural lips in the Victoria specimens is more pronounced, being drawn out more sharply than it is in the Idaho material. Perhaps the highly compressed stipes in the Idaho specimens created the difference in appearance of the apertural lips. Because the Idaho specimens are not fully similar to the Victoria specimens, they have been compared closely to them.

Didymograptus cf. D. nicholsoni planus Elles and Wood, 1901

Plate 2, figure 6

The rhabdosomes are generally extensiform and horizontal, but they have a shallow V shape in the proximal region. The stipes diverge from the sicula initially at a 120° to 140° angle, and they are declined. The stipes curve to the horizontal by the fourth to sixth theca. The stipes are as much as 28 mm long, and they widen from 0.4 to 0.5 mm across the first thecal apertures, to 0.8 to 0.9 mm at 5 mm from the first thecal apertures, to a maximum of 0.9 to 1.0 mm 8 to 10 mm from the first thecal apertures. Maximum stipe width is maintained throughout the remainder of the stipe.

Thecae number 10 to 11 in 10 mm. Proximal thecae are inclined 25° to 30° to the stipe axis, and distal thecae are inclined 20° to 25° to the stipe axis. Thecal apertures are straight and form a 5° to 12° angle with a line normal to the stipe axis. Thecal overlap is one-half, and thecae are three times as long as they are wide. Ventral thecal walls are straight; the thecae have a relatively simple tubular shape.

Siculae are 1.0 to 1.2 mm long and 0.2 to 0.3 mm wide at the aperture.

Figured specimen.—USNM 241115.

Occurrences.—USGS colln. D2597 CO.

Discussion.—Rhabdosome shape and thecal characteristics are distinctive features of these rhabdosomes. The specimens are similar to *D. nicholsoni planus* Elles and Wood in rhabdosome shape and size. They are more similar to *D. nicholsoni* Lapworth than to the subspecies *planus* in angle of thecal inclination. Elles and Wood (1901, p. 29) noted that subspecies *planus* may be distinguished from *D. nicholsoni* both by rhabdosome shape and thecal angle of inclination. The Idaho specimens appear to have the shape of subspecies *planus,* but they agree in all other characteristics with *D. nicholsoni* s.s. Inasmuch as the two subspecies of *D. nicholsoni* are similar except for shape and thecal inclination and some slight overlap in range in variation in thecal inclination may exist between the two subspecies, the Idaho specimens are referred to the subspecies *planus* because they are so closely similar in shape.

Didymograptus protobifidus Elles, 1933

Plate 2, figure 1

Didymograptus protobifidus Elles, 1933, Great Britain Geol. Survey Summ. Prog. 1932, pt. 2, p. 98, figs. 1–3.

The rhabdosomes are pendent. Stipe lengths as much as 17 mm are present in the specimens at hand. The stipes widen from 0.4 to 0.5 mm at the first thecal apertures on each stipe, to 0.9 to 1.0 mm 5 mm from the first thecal apertures, to the maximum width of 1.0 to 1.2 mm 6 to 10 mm from the first thecal apertures. Maximum stipe width is maintained for the remainder of their extent. The stipes diverge from each other initially at an 80° to 90° angle, but they curve markedly in the proximal 4 to 5 mm of the rhabdosome to become subparallel. Distal parts of the stipes form a 5° to 10° angle with each other.

Thecae number 13 in 10 mm. They are slender tubes which, at maturity, are 3½ to 4 times as long as they are wide and overlap about one-half their length. The thecae are slightly curved, being inclined to the stipe axis at a 30° to 35° angle in their inner parts and at a 35° to 45° angle near their apertures. Thecae in the distal part of the stipes are more curved than those ithe proximal part. The proximal one to three thecae are curved slightly. The proximal two or three thecae are about twice as long as they are wide, whereas thecal length to width ratio increases in the medial and distal parts of the stipe.

Sicula length is 0.8 to 1.1 mm, and sicula width at the aperture is 0.3 to 0.4 mm.

Figured specimen.—USNM 241116.

Occurrence.—USGS colln. D2596 CO.

Discussion.—The Idaho specimens are closely similar to typical specimens described by Elles (1933) in all characters. The species is typified by its pendent form, slender stipes (the distal parts of which are nearly parallel), and slightly curved thecae. Thecae in *D. protobifidus* are less curved than they are in other members of the *D. bifidus* group. Rhabdosome shape, with its slender subparallel stipes, distinguishes the species from other members of the group as well.

Thecal spacing is slightly closer (commonly 14 or 15 in 10 mm in *D. bifidus*), thecal curvature greater, stipe width more, and divergence of the distal parts of the stipes wider in *D. bifidus*.

An immature specimen having characteristics suggestive of closer affinities to *D. bifidus* than to *D. protobifidus* was found stratigraphically slightly above most of the *D. protobifidus* specimens. The single specimen has seven thecae in the proximal 5 mm, a stipe width of 1.2 mm at 5 mm (compared with 1.0 mm in *D. protobifidus* at this position), stipe divergence of about 12°, and apparently slightly more curved thecae in the proximal region. The specimen (pl. 2, fig. 2) could be an immature *D. bifidus* or a *D. protobifidus-D. bifidus* transient. Its presence suggests that development toward *D. bifidus* may have been taking place in the local *D. protobifidus* population.

Didymograptus sp.

Plate 2, figures 4, 5

The rhabdosome is horizontal. The stipes diverge from the sicula at 180°, and they are as much as 87 mm long. Stipe width is 0.5 to 0.6 mm across the apertures of the first thecae on each stipe. Width increases to 0.9 to 1.0 mm 5 mm from the first thecal apertures to a maximum width of 1.4 to 1.5 mm 10 to 12 mm from the first thecal apertures.

Thecae number 9½ to 10 in 10 mm. Angle of thecal inclination is 30° to 35°. Thecal overlap is about one-half, and thecae are about three times as long as they are wide. Thecal apertural margins are concave and have a slight flangelike projection formed where the free ventral wall joins the apertural margin.

Siculae are about 1.0 mm long and 0.3 to 0.4 mm wide at the aperture.

Figured specimens.—USNM 241117, 241118.

Occurrence.—USGS collns. D2502 CO, D2503 CO, D2504a CO, D2504b CO, D2516c CO, D2545 CO, D2560 CO, D2590 CO, D2693a CO, D2693g CO, D2693h CO.

Discussion.—The rhabdosome is characterized by its horizontal shape, relatively slow rate at which the stipes widen, and projections from the apertural margins. The shape of the apertural margin suggests comparison with *D. cuspidatus* Rudemann, *D. acutidens* Elles and Wood, and *D. distinctus* Harris and Thomas. Rhabdosome shape is horizontal whereas it is not horizontal in *D. acutidens*, although thecal shape is most similar to that of *D. acutidens*. Thecae in *D. distinctus* are shorter and broader, overlap less, and are more highly inclined than in the Idaho material. Thecae in *D. cuspidatus* are more denticulate and rhabdosome shape includes a shallow V shape in the proximal part in *D. cuspidatus*; whereas the Idaho specimens are horizontal, and the thecal apertures are not as cusplike as in *D. cuspidatus*.

Genus CARDIOGRAPTUS Harris and Keble, in Harris, 1916

Cardiograptus rhabdosomes are biserial with a prominent "notch" in the distal part of the rhabdosome formed apparently by thecae that started but did not develop a distinct stipe.

Cardiograptus morsus Harris and Keble, 1916

Plate 4, figures 3, 5

Carbiograptus morsus Harris and Keble. Harris, 1916, Royal Soc. Victoria Proc., v. 29, new ser., pt. 1, pl. 1, figs. 1–4.
Cargiograptus morsus Harris and Keble. Harris, 1924, Royal Soc. Victoria Proc., v. 36, new ser., pt. 2, p. 95–96.

The rhabdosomes are biserial and have an elongate oval shape with distal emargination. They range from 12 mm long and 6.5 mm in maximum width to 23 mm long and 8.2 mm maximum width. They are 2.6 to 3.5 mm wide across the apertures of the second thecal pair, and they widen to their maximum width by the eighth or ninth thecal pair. The notch at the emarginate distal end of the rhabdosome ranges from 2.6 mm deep in smaller or immature specimens to 5.5 mm deep in the most mature rhabdosomes in the collections. The stipes on each side of the notch range from 2.6 mm to 3.5 mm in width at the base of the notch, and they taper distally.

Thecae number 6 in the proximal 5 mm, 5 to 5½ in 5 mm in the proximal parts of the rhabdosome, and 8½ to 9 in 10 mm in the distal part of the longest rhabdosomes. The thecae have markedly curved ventral thecal walls. Seven to nine thecae in the proximal part of the rhabdosome are pendent. Proximal parts of the scandent thecae in the proximal region of the rhabdosome are inclined at a 35° to 45° angle to the rhabdosome axis. Proximal parts of thecae in the distal part of the rhabdosomes are inclined at a 25° to 35° angle to the rhabdosome axis. The ventral thecal walls of all thecae are markedly curved. Those of thecae in the medial and distal part of the rhabdosome are more curved than those of thecae in the proximal part. Thecae are in contact throughout their length. The ventral thecal walls become concave close to the join with the apertural margin. Thecal apertural margins are gently concave, and the join of the apertural margin with the ventral thecal wall is drawn into the denticle.

Siculae were not observed except for their apertural margins, which are concave and bear a stout denticle or virgella. The denticle of the sicula aperture and of the aperture of Th 1[1] appear to be closely pressed together. A median septum that appears to be complete is present.

Figured specimen.—USNM 241119, 241120.

Occurrence.—USGS collns. D2516a CO, D2693a CO, D2693h CO.

Discussion.—The Idaho specimens show a relatively wide range of elongate oval shapes, but they appear to fall within the range in variation in rhabdosome shape, in thecal shape and spacing, and in apertural characteristics of the typical Victoria (Australia) specimens. The elongate oval shape and marked notch at the distal end of the rhabdosome as well as the thecal shape are characteristic of this species.

Genus ISOGRAPTUS Moberg, 1892

Cooper (1973) discussed definition of the Genus *Isograptus* and emended Bulman's (1970) diagnosis somewhat. Cooper (1973, p. 55) noted that among isograptids the "first theca arises near the apex of sicula, the two forming a symmetrical pair such that the axis of rhabdosome symmetry passes between their free ventral walls." Cooper (1973, p. 55) went on to state that "the sicula and the first theca attain almost identical proportions and form a symmetrical pair about the rhabdosome midline." The orientation and sizes of the first theca and sicula are characteristic of members of the genus *Isograptus* and spearate them from reclined didymograptids, such as *D. hemicyclus* Harris, as Cooper (1973, p. 57) indicated.

Isograptus caduceus australis Cooper, 1973

Plate 3, figure 2; text figures 7, 8

Isograptus caduceus australis Cooper, 1973, Palaeontology, v. 16, pt. 1, p. 74–77, text figs. 16a–h.

The rhabdosomes are of relatively moderate size and have an approximate V shape. The longest stipes are 20 mm. Stipes flex markedly initially, but their medial and distal parts are straight and diverge at angles of 320° to 340°. Stipes are 2.0 to 2.5 mm wide at the apertures of the first thecal pair. They taper to 1.6 to 1.9 mm at the fifth pair of thecae and to 1.5 to 1.9 mm in the distal parts of the longest stipes.

Thecae number 4½ to 5 in 5 mm. The initial two or three thecae of each stipe are relatively long, straight, and directed downward. Succeeding thecae are shorter, wider, curved, and inclined to the stipe axis. Angles of thecal inclination to the stipe axis of thecae that are curved are greater in the proximal part of the rhabdosome than in the distal part. Free ventral walls in the medial and distal parts of the stipes are linclined 30° to 40° for much of their length. Inclination of the free ventral walls increases to 65° to 75° close to the apertures. Thecal apertures are slightly concave and denticulate and are somewhat more denticulate in the proximal part of the rhabdosome than in the distal part.

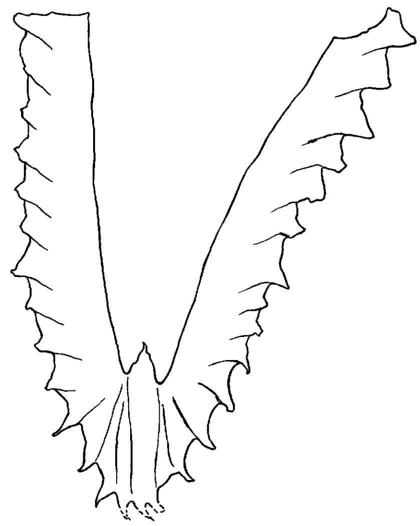

FIGURE 7.—*Isograptus caduceus australis* Cooper. Drawing from photograph showing great vertical width of proximal part. × 5. USNM 241122. USGS colln. D2693a CO. Dashed where reconstructed.

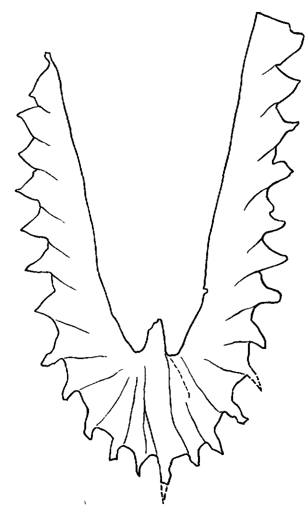

FIGURE 8.—*Isograptus caduceus australis* Cooper. Drawing from photograph showing great vertical width of proximal part and tapering of stipes. × 5. USNM 241123. USGS colln. D2693a CO. Dashed where reconstructed.

Siculae are 3.4 to 3.8 mm long and 0.5 to 0.9 mm wide at their apertures. Siculae are free 0.7 to 1.1 mm. The identation between the ventral walls of the sicula and first theca appears to be a narrow slit in most specimens, but the ventral walls of the first theca and sicula seem to be in contact throughout their length in a few specimens. The apertural margins of the proximal thecae that are pendent and the sicula bear small apertural processes. The apertural processes in the sicula and first theca may extend downward relatively prominently. Pendent thecae number five to seven, with an average of six.

Figured specimens.—USNM 241121, 241122, 241123.

Occurrence.—USGS collns. D2516a CO, D2693a CO, D2693c CO, D2693d CO.

Discussion.—Idaho specimens of *I. caduceus australis* appear similar to Australian-New Zealand specimens of the same subspecies in vertical breadth of the proximal part of the rhabdosome, in general rhabdosome shape, in the distal tapering aspect of the stipes, and in sicula dimensions. Stipe widths may be slightly greater in the Idaho specimens. The Idaho specimens appear to be relatively highly compressed; their measured stipe width may be either a real difference between specimens from the two different places, or it may reflect greater compression.

Isograptus caduceus imitatus Harris, 1933

Plate 3, figure 3; plate 5, figures 5, 6; text figure 9

Isograptus caduceus var. *imitata* Harris, 1933, Royal Soc. Victoria Proc., v. 46, New ser., pt. 1, p. 92, figs. 55-59.

Isograptus caduceus imitatus Harris. Cooper, 1973, Palaeontology, v. 16, pt. 1, p. 71-74, text figs. 14a-i.

The rhabdosomes are relatively small and have essentially a V shape. The longest stipes are 8 to 10 mm. The stipes flex sharply initially, but their medial and distal parts are straight and diverge at angles of 320° to 330°. The stipes are widest close to the sicula, being 1.6 to 2.1 mm wide proximally. The stipes taper distally to about 1.3 mm wide in the distal part of the longer stipes.

Thecae number six or seven in 5 mm. The initial one or two thecae of each stipe are relatively long and straight and are directed downward. Succeeding thecae are shorter, more curved, and highly inclined to the stipe axis. Distal thecae are inclined at lower angles to the stipe than the proximal thecae. The free ventral walls in distal thecae are inclined at about 30° to the stipe axis. Thecal apertures are denticulate. They are markedly denticulate in the proximal thecae, but less so in medial and distal thecae.

The siculae are 2.5 to 3.1 mm long and 0.5 to 0.6 mm wide at their apertures. Siculae are free 0.9 to 1.1 mm. The notch between the first thecae and sicula is about 0.8 mm deep and 0.3 mm wide at the level of the first thecal aperture. The apertural margins of both the first theca and the sicula are extended into a prominent ventral spinelike process. Four or five pendent thecae are present in the proximal region.

Figured specimens.—USNM 241124, 241125, 241126, 241127.

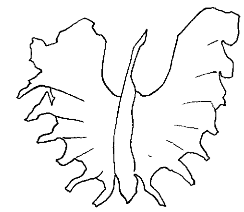

FIGURE 9.—*Isograptus caduceus imitatus* Harris. Drawing from photograph showing rhabdosome size and great vertical width of proximal part. × 5. USNM 241127. USGS colln. D2693c CO.

Occurrences.—USGS collns. D2516a CO, D2693c CO, D2693d CO, D2693g CO.

Discussion.—The Idaho specimens are closely similar to Australian and New Zealand specimens in nearly all features. The Idaho specimens have a somewhat deeper proximal region produced by slightly longer proximal thecae of each stipe. Initial stipe width of the Idaho specimens (commonly about 2 mm) is greater than it is in the Australian and New Zealand specimens (commonly about 1.5 mm). The characteristic features of relatively small rhabdosome size, approximate V shape, small deep notch between $Th1^1$ and the sicula, and denticulate thecae that have more marked denticulate apertures in proximal than in distal thecae ally the Idaho and Australian-New Zealand specimens.

Isograptus forcipiformis (Ruedemann, 1904)

Plate 5, figure 4

Didymograptus forcipiformis Ruedemann, 1904, New York State Mus. Mem. 7, p. 699-700, text fig. 91, pl. 15, figs. 10-13.

Isograptus forcipiformis (Ruedemann). Ruedemann, 1947, Geol. Soc. America Mem. 19, p. 352-353, pl. 57, figs. 37-40.

Isograptus forcipiformis (Ruedemann). Cooper, 1971, Jour. Paleontology, v. 45, no. 5, p. 906, text figs. 3a-e.

One complete, mature rhabdosome was found in addition to some immature and incomplete rhabdosomes. The stipes are as much as about 16 mm long. They decrease from 1.9 mm in the proximal part to 0.9 to 1.0 mm in the distal part. The stipes curve rapidly in the proximal region to become scandent and to diverge from each other at an angle of 350° for most of their length.

Thecae number nine in 10 mm. The first two thecae are straight, about 2 mm long, and are pressed against the side of the sicula for most, if not all, of their length. Thecal apertures of the proximal thecae have distinct apertural processes that project downward from the apertures. Thecal curvature is more marked in the proximal thecae (except the initial theca of each stipe) than it is in the thecae in the medial and distal parts of the stipes. Thecal overlap is almost total among all thecae. All thecal apertures have a distinct flange, and the flange is slightly more pronounced in proximal than in distal thecae. Inner parts of thecae in the medial and distal parts of the stipes are inclined at a 30° to 40° angle to the stipe axis. Outer parts of the same thecae are oriented nearly normal to the stipe axis. Thecal apertural margins are concave.

The sicula is 3.4 mm long and 1.0 mm wide at its aperture. A relatively stout nema extends at least 2 mm above the sicula apex.

Figured specimen.—USNM 241128.

Occurrence.—USGS collns. D2693c CO, D2693e CO, D2693g CO, D2693h CO.

Discussion.—The Idaho specimens are similar to typical material from New York in all characters except sicula length, which is slightly greater in New York specimens. The most distinctive features of *I. forcipiformis* are a relatively deep proximal part of the rhabdosome, tapering stipes that diverge at angles of 350° to 360° from each other, and little or no notch between the ventral walls of the first theca and the sicula. *I. forcipiformis* appears to be distinct from *I. caduceus* because the stipes taper more markedly and are oriented more nearly upward than in *I. caduceus.* Additionally, a slight but significantly deep notch is present between the first theca and sicula in *I. caduceus*; whereas the notch is slight in *I. forcipiformis.*

Isograptus victoriae lunatus Harris, 1933

Plate 5, figures 1, 8; text figure 10

Isograptus caduceus var. *lunata* Harris, 1933, Royal Soc. Victoria Proc., v. 46, new ser., pt. 1, p. 90, text figs. 4-6.

Isograptus victoriae lunatus Harris. Cooper, 1973, Palaeontology, v. 16, pt. 1, p. 59-62, text figs. 8a-k, n.

The rhabdosomes are relatively small and have a generally U shaped proximal part. Stipe lengths are as much as 5 mm. Stipes are 1.6 to 1.9 mm wide. They are approximately constant in width, although stipes in some specimens appear to widen slightly in their medial parts as a consequence of compressional differences. The stipes curve upward relatively gradually to give the proximal part of the rhabdosomes a gently rounded aspect.

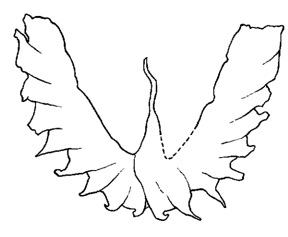

FIGURE 10.—*Isograptus victoriae lunatus* Harris. Drawing from photograph showing rhabdosome form and size. × 5. USNM 241131. USGS colln. D2693b CO. Dashed where reconstructed.

Thecae in the longest specimen number six in 5 mm. Thecal ventral walls are markedly curved, and ventral walls of thecae in proximal region are more curved than in relatively distal thecae. Ventral walls in proximal thecae are inclined at angles of 70° to 80° to the stipe axis for most of their length, but they curve sharply near their join with the apertural margin to become nearly normal to the stipe axis. Most of the ventral walls in relatively distal thecae are inclined to the rhabdosome axis at angles of about 30° to 40°, but they curve sharply near the join with the apertural margins to form about a 70° to 75° angle with the stipe axis. Thecal apertural margins are concave, and they are drawn into prominent denticulate extensions where they join the ventral walls.

Siculae are 2.6 to 3.2 mm long and 0.5 to 0.8 mm wide at their apertures. A nema that is at least 18 mm long is present in one specimen. A ventral process that is 0.5 to 0.6 mm long extends down from the apertures of the sicula and first theca to provide a distinctive denticulate aspect to the proximal region of the rhabdosomes. An indentation that is 0.5 to 0.6 mm wide at the level of the first thecal aperture is formed between the ventral walls of the first theca and sicula. Four to six pendent thecae are present in the proximal region.

Figured specimens.—USNM 241129, 241130, 241131.

Occurrence.—USGS collns. D2502 CO, D2551 CO, D2597 CO, D2693b CO.

Discussion.—Characteristic features of *I. victoriae lunatus*, which it shares with other subspecies of *I. victoriae*, are the relatively wide indentation between the ventral walls of the first theca and the sicula, and comparatively constant width of the stipes, the relatively long nema, and the broadly U shaped proximal part of the rhabdosome. *I. victoriae lunatus* may be distinguished from other subspecies of *I. victoriae* by its relatively narrow stipes. The Idaho specimens are similar to Australian and New Zealand specimens of *I. victoriae lunatus* in most characters. They are, compared with the dimensions cited by Cooper (1973) for New Zealand specimens, among the larger specimens that may be assigned to *I. victoriae lunatus.*

Isograptus victoriae victoriae Harris, 1933
Plate 4, figure 2; text figure 11

Isograptus caduceus var. *victoriae* Harris, 1933, Royal Soc. Victoria Proc., v. 46, new ser., pt. 1, p. 90, figs. 7-10.
Isograptus victoriae victoriae Harris. Cooper, 1973, Palaeontology, v. 16, pt. 1, p. 62-63, text figs. 9a-f.

The stipes are as much as 11 mm long, and they are approximately the same width from their origin to close to the distal tips, where they narrow because thecae there are immature. Stipe width is 2.2 to 2.4 mm. The stipes curve markedly but form a rhabdosome having a basically U shaped proximal part.

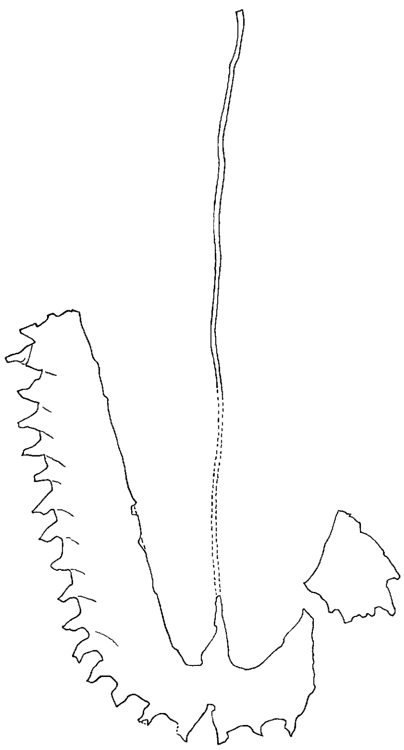

FIGURE 11.—*Isograptus victoriae victoriae* Harris. Drawing from photograph showing rhabdosome size and shape and long tubular nema. × 5. USNM 241133. USGS colln. D2597 CO. Dashed where reconstructed.

Thecae number five in 5 mm. Ventral walls of thecae in the proximal part of the rhabdosome curve strongly. Ventral walls of proximal thecae are inclined at angles of 60° to 70° to the stipe axis for most of their length, but the ventral walls curve to become approximately normal to the stipe axis close to the join with the aperture. Ventral walls of thecae in the distal part of the rhabdosome are inclined at an angle of about 30° to the stipe axis for most of their length, but they curve so that the part close to the join with the thecal aperture forms a 60° to 70° angle with the stipe axis. Thecal apertures are markedly concave, and they are extended into denticles where they join the ventral walls. Thecal overlap is nearly complete.

Siculae are 3.4 to 3.9 mm long. They are 0.6 to 0.9 mm wide at their apertures, and they are free 1.5 to 1.9 mm. A long nema appears to be present in at least one specimen. Sicula apertures have a prominent ventral process that extends downward from the aperture for 0.5 to 0.8 mm. A relatively wide indentation or notch is present between the free ventral wall of the first theca and sicula. The indentation is 0.6 to 0.7 mm wide at the level of the first thecal aperture, and the indentation is about as deep as it is wide at the position of the first thecal aperture. Four to seven pendent thecae are present.

Figured specimens.—USNM 241132, 241133.
Occurrence.—USGS collns. D2503 CO, D2516c CO, D2597 CO.

Discussion.—Although some specimens of *I. victoriae victoriae* may have a more nearly V shape than U shape and so resemble specimens of *I. caduceus australis, I. victoriae victoriae* may be distinguished from *I. caduceus* by its relatively wide indentation between the first theca and sicula, its nearly constant stipe width, its slightly shorter ventral processes on apertures of the sicula and first theca, and its slightly less deep and more rounded aspect of the proximal part of the rhabdosome. The Idaho specimens, although somewhat distorted by deformation, have the characteristic features of *I. victoriae victoriae.* Specimens of *I. victoriae victoriae* may be distinguished from *I. victoriae lunatus* Harris by their wider stipes. Dimensions of the Idaho specimens fall within the range of variation of Australian and New Zealand specimens of *I. victoriae victoriae.*

Genus PSEUDISOGRAPTUS Beavis, 1972

The isograptids having a distinct manubrium—the species *dumosus, hastatus,* and *manubriatus*—have generated considerable debate concerning their affinities (Skevington, 1968; Bulman, 1968; Beavis, 1972; Cooper, 1973). Cooper (1973) carefully reviewed isograptids and drew attention to the symmetrical arrangement of the first theca and sicula in all of them and in the three species having a manubrium as well. Cooper (1973, p. 88) commented that the isograptids having a manubrium probably form a distinct group. He noted that that group was typified by the "proximal symmetry and highly inclined proximal thecae of *Isograptus,* and the proximal concentration of thecal origins, the prothecal folds, and the low inclination of distal thecae of *Meandrograptus.*" The group may well eventually warrant separation as a distinct subgenus within *Isograptus.*"

At the time that Cooper's (1973) review of isograptids was in press, Beavis (1972) published a short analysis of isograptid species having a manubrium and suggested grouping them within the genus *Pseudisograptus*. The most characteristic aspect of the genus *Pseudisograptus*, at least the most characteristic aspect that may be detected in highly compressed rhabdosomes, is the manubrium. The manubrium appears to have developed as a consequence of the clustering of the origins of many thecae about the sicula. Because the manubrium is a distinctive feature and because Cooper (1973) suggested that recognizing the isograptids having a manubrium as a distinct group might be appropriate, the generic name *Pseudisograptus* proposed by Beavis (1972) is used here.

The systematic position of the genus *Pseudisograptus* remains to be considered more fully when well-preserved isolated specimens of species having a manubrium have been found and studied. For the present, a systematic position near *Isograptus* is perhaps appropriate. Beavis (1972) suggested that his genus *Pseudisograptus* might be placed in the family Sinograptidae Mu. Members of the Sinograptidae commonly have prothecal folds and some form of introversion about the aperture. The isograptids having a manubrium have thecal apertures as in other isograptids, and, in general, lack apertural introversion. A degree of prothecal folding is present, however, in *P. manubriatus*.

Pseudisograptus dumosus (Harris, 1933)
Plate 3, figure 5; plate 5, figure 3

Isograptus dumosus Harris, 1933, Proc. Royal Soc. Victoria Proc., v. 46, new ser., pt. 1 p. 94, text figs. 37-30, pl. 6, figs. 2a-c.
Isograptus dumosus Harris. Cooper, 1973, Palaeontology, v. 16, pt. 1, p. 78-82, text figs. 18a-p.

The specimens are 4.2 to 4.7 mm wide and 4.5 to 5.0 mm in height. The manubrium is 2.2 to 2.5 mm wide at its base. The apex of the sicula and first theca extend about 1 mm above the apex of the manubrium. Siculae are 3.8 to 4.2 mm long and 0.6 to 0.8 mm wide at their apertures. Stipes are slightly developed above the manubrium.

Figured specimens.—USNM 241134, 241135.

Occurrence.—USGS collns. D2504a CO, D2516a CO, D2516b CO, D2693g CO.

Discussion.—A large, rapidly expanding manubrium and slightly developed stipes characterize this species. The Idaho specimens are similar to forms described by Cooper (1973, p. 80-82) as *I. dumosus* form B in sicula length, rhabdosome width, and manubrium size and shape. The Idaho specimens differ from the New Zealand specimens described by Cooper (1973, p. 80-82) in possessing slightly less well developed stipes and in slightly wider siculae.

Pseudisograptus manubriatus (T. S. Hall, 1914)
Plate 3, figure 4; plate 5, figure 7

Didymograptus caduceus var. *manubriatus* T. S. Hall, 1914, Royal Soc. Victoria Proc., v. 27, new ser., pt. 1, p. 108-109 (part), pl. 17, fig. 12.
Isograptus manubriatus (T. S. Hall). Harris, 1933, Royal Soc. Victoria Proc., v. 46, new ser., pt. 1, p. 102-104, text figs. 41-44, pl. 1, figs. 2a-i.
Isograptus manubriatus (T. S. Hall) *sensu lato*. Cooper, 1973, Palaentology, v. 16, pt. 1, p. 84-88, text figs. 22a-q.

The rhabdosomes are broadly U shaped. The stipes curve gently throughout. They diverge from each other at a 310° to 330° angle. The stipes are 10 to 15 mm long, and they widen from about 1.5 to 1.7 mm at their origins to a maximum of 1.6 to 1.8 mm.

Siculae are 4.3 to 4.6 mm long, and they are about 0.5 mm wide at the aperture. The manubrium is essentially wedge shaped. It is about 1 mm high and 1.2 to 1.7 mm wide at the base. That part of the sicula that extends above the manubrium appears to be joined by the proximal part of the first theca with the result that the two appear to form a tubular structure that continues upward into the nema. The sicula apex and proximal aprt of the first theca extend approximately 2.5 mm above the apex of the manubrium.

Thecae number six in 5 mm. Proximal-region thecae appear to curve markedly. Their inner parts form a 30° to 40° angle with the stipe axis, and their outer parts form a 60° to 70° angle with the stipe axis. The most distal thecae on the stipes have markedly lesser angles of inclination. Their inner parts are inclined at a 10° to 20° angle to the stipe axis, and their outer parts are inclined at a 20° to 35° angle to the stipe axis. Thecal apertures bear a distinct apertural process that appears almost spinelike in profile view of highly compressed specimens.

Figured specimens.—USNM 241136, 241137.

Occurrence.—USGS collns. D2516a CO, D2516b CO.

Discussion.—The Idaho specimens are poorly preserved, but they appear to be consistent with Cooper's (1973) description of specimens he considered as being within the range in variation of the species. The Idaho specimens have a relatively small manubrium, but it has the wedge shape and relative height indicated by Cooper (1973, p. 86) as being characteristic for the species. In addition, the apex of the sicula and the proximal part of the first theca form a conspicuous tubular structure that projects above the manubrium apex and appears to extend into the nema, as described by Cooper (1973, p. 86) for *P. manubriatus*. Ventral thecal walls curve significantly, those of the distal-region thecae being less markedly curved than those of the proximal region. Stipe width of the Idaho specimens may be somewhat less than in most Australian and New Zealand specimens of *P. manubriatus*; but considerable range in variation in stipe width appears to exist among typical specimens, and the Idaho specimens fall within the range in variation.

Pseudisograptid?
Plate 5, figure 2

Three specimens of highly compressed graptolites that appear to possess a prominent manubrium and very short stipes are present in the collections. The apparent sicula is 2.5 to 2.7 mm long. Its apex rises approximately 0.7 to 0.8 mm above a manubriate structure that expands relatively rapidly to a width of 1.5 to 1.7 mm at its base. Apparent stipes are 0.7 to 0.9 mm wide. What may have been thecae are preserved on one specimen. Their shape is suggestive of thecae in *Meandrograptus.*

Figured specimen.—USNM 241138.

Occurrence.—USGS colln. D2516a CO.

Discussion.—Rhabdosome shape and the relatively rapidly expanding manubriate structure suggest that this group of specimens may belong to *Pseudisograptus* or to *Meandrograptus*. The size of the probable manubrium, the length of the sicula, and the essentially triangular outline of the sicula and manubriate structure and proximal part of the rhabdosome suggest that these specimens might be *Meandrograptus aggestus* Harris (1933). Cooper (1973, text fig. 24c) illustrated the holotype of *Meandrograptus aggestus* Harris. The dimensions of the sicula and manubrium in that specimen, which is from Victoria, Australia, and the dimensions of what are probably these structures in the Idaho specimens are similar. Because thecal characters may not be examined closely in the Idaho specimens, their possible relationships with *Meandrograptus* or *Pseudisograptus* may only be noted.

Genus ONCOGRAPTUS T. S. Hall, 1914

Oncograptus is characterized by rhabdosomes that are initially biserial and scandent but that become uniserial in the distal part. The uniserial stipes diverge from each other at a low angle and so are highly inclined.

Oncograptus upsilon T. S. Hall, 1914
Plate 2, figure 3; plate 4, figure 1

Oncograptus upsilon T. S. Hall, 1914, Royal Soc. Victoria Proc., v. 27, new ser., pt. 1, p. 109, pl. 17, fig. 14.

Oncograptus upsilon T. S. Hall. Ruedemann, 1947, Geol. Soc. America Mem. 19, p. 355-356, pl. 58, fig. 5.

Oncograptus upsilon T. S. Hall. Berry, 1960, Texas Univ. Bur. Econ. Geol. Pub. 6005, p. 68, pl. 11, figs. 10, 15.

Only two incomplete specimens were found, but the characteristic partly biserial and partly uniserial rhabdosome shape may be seen. The biserial part of the rhabdosome is 7.3 to about 9 mm long. It widens from 1.5 mm across the first pair of thecae to about 5.3 mm 5 mm from the first thecal pair. The rhabdosome is approximately 2.5 mm wide at bifurcation where the biserial part of the rhabdosome gives rise to two uniserial stipes. The longest uniserial stipe is approximately 12 mm long. Uniserial stipes are about 3 mm wide.

Thecae number 6 in the biserial part of the rhabdosome and 4½ to 5 in 5 mm on the uniserial stipes.

Figured specimen.—USNM 241139, 241140.

Occurrence.—USGS colln. D2693a CO.

Suborder GLOSSOGRAPTINA Jaanusson, 1960

Glossograptina rhabdosomes are biserial, monopleural in development, and have a pericalycal proximal end.

Family GLOSSOGRAPTIDAE Lapworth, 1973

Glossograptid rhabdosomes are highly spinose and thecae are orthograptid.

Genus GLOSSOGRAPTUS Emmons, 1855

Members of the genus *Glossograptus* possess not only apertural but also lateral and, apparently, dorsal spines.

Glossograptus acanthus Elles and Wood, 1908
Plate 6, figure 6

Glossograptus acanthus Elles and Wood, 1908, Palaeontographical Soc., v. 62, pt. 7, p. 314, pl. 33, figs. 4a-c.

Glossograptus acanthus Elles and Wood. Harris and Thomas, 1935, Royal Soc. Victoria, Proc., v. 47, new ser., pt. 2, p. 302-303, fig. 3, nos. 13-16.

Glossograptus acanthus Elles and Wood. Ross and Berry, 1963, U.S. Geol. Survey Bull. 1134, p. 99, pl. 5, figs. 18, 19.

The specimens have a somewhat fusiform shape. They are as much as 15.5 mm long. They widen from 1.5 to 1.8 mm wide across the aperture of the first theca to the maximum width of 3.0 to 3.4 mm by the third or fourth pair of thecar (width is measured without thecal spines). The rhabdosomes then remain parallel sided throughout the remainder of their extent.

Thecae number 11 to 12 in 10 mm. The thecae are orthograptid in type, and they bear relatively stout spines that are 1.0 to 1.3 mm long. The spines originate from moderately everted apertural lips. The thecae appear to overlap about one-half, and their free ventral walls form a 45° to 53° angle with the rhabdosome axis.

Development at the proximal end is clearly cryptograptid. Two sicular spines are present and the spines on the first thecal pair droop downward to give the rhabdosome a four-spined proximal end.

Figured specimen.—USNM 241141.

Occurrence.—USGS collns. D2693c CO, D2693f CO.

Discussion.—The Idaho rhabdosomes are similar in rate of rhabdosome widening, rhabdosome maximum width, and thecal spacing to other specimens from the Western United States and also those from Victoria, Australia, examined by the author. The United States and Victoria specimens placed in this species differ from the typical British members of the species in being slightly narrower (British species widen to 4 mm), in widening to maximum rhabdosome width slightly more rapidly than British specimens and in slightly more closely spaced thecae (most British specimens have a thecal spacing of 10 in 10 mm). The spines in most Victoria and Western United States specimens appear to be slightly shorter than those in British specimens. The differences between typical British specimens and those from both the Western United States and Victoria, Australia, appear to be of about subspecific magnitude. The characters of spine robustness and origin, rhabdosome form, and thecal characteristics appear to ally the Western United States and Victoria specimens with the British in the species *G. acanthus*. The Victoria and Western United States specimens seem to occur at a stratigraphically hnigher position than do the British; hence, the Victoria and Western United States specimens may constitute a temporal subspecies (as well as a geographic subspecies) within the species.

Glossograptus hincksii (Hopkinson, 1872)

Plate 2, figure 8; plate 6, figure 1; text figure 12

Diplograptus hincksii Hopkinson, 1872, Geol. Mag., v. 9, p. 507–508, pl. 12, fig. 9.

Glossograptus hincksii (Hopkinson). Elles and Wood, 1908, Palaeontographical Soc., v. 62, pt. 7, p. 309–312, pl. 33, figs. 2a–j.

Glossograptus hincksii (Hopkinson). Berry, 1960, Texas Univ. Bur. Econ. Geol. Pub. 6005, p. 71, pl. 12, fig. 9a.

Glossograptus hincksii (Hopkinson). Ross and Berry, 1963, U.S. Geol. Survey Bull. 1134, pl. 5, figs. 25, 26.

The rhabdosomes have a parallel-sided appearance for most of their length. Only incomplete rhabdosomes were found, but the longest of them is about 19 mm. The rhabdosomes widen from about 2 mm across the first thecal pair to their maximum width of 3.2 to 3.6 mm within 5 to 7 mm from the first thecal pair. They maintain maximum width for the remainder of their extent.

Thecae number 7 to 8 in the proximal 5 mm, 5½ in the distal 5 mm, and 11½ to 12 in 10 mm in the medial to distal parts of the rhabdosome. Thecae are essentially orthograptid in aspect, but their apertural margins are drawn into marked flanges that bear spines. Thecal apertural spines are as much as about 2 mm long. Lateral spines as much as 5 mm long are preserved on some specimens. Lateral spines are thinner and more arcuate than apertural spines.

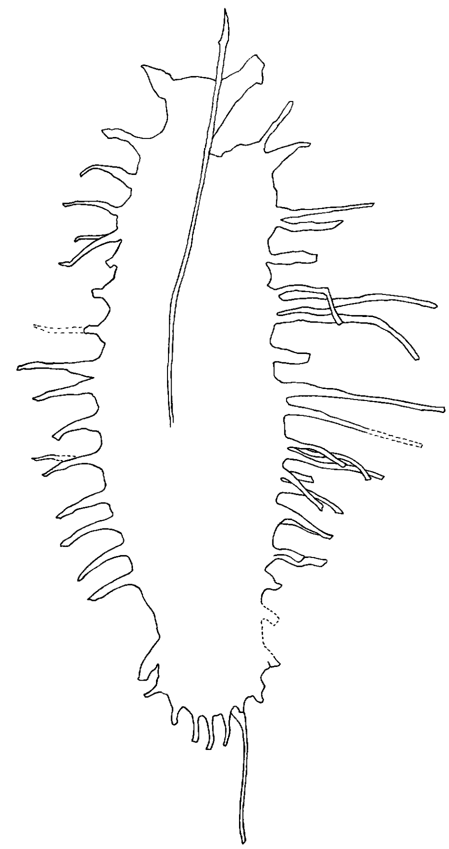

FIGURE 12.—*Glossograptus hincksii* (Hopkinson). Drawing from photograph showing rhabdosome shape and spine arrangement. × 5. USNM 241144, USGS colln. D2693h. Dashed where reconstructed.

The proximal end of the rhabdosome appears similar to that in *Cryptograptus*. Both Th 1^1 and 1^2 bear spines that droop downward. The sicula aperture appears to have two short downwardly directed spines. The first pair of thecae appear to be directed essentially downward; whereas the second and all succeeding pairs of thecae are directed upward.

A thin but relatively long virgula is present. The virgula in one specimen appears to be approximately

15 mm long, about as long as the remainder of the rhabdosome.

Figured specimens.—USNM 241142a, 241143, 241144.

Occurrence.—USGS collns. D2516a CO, D2693a CO, D2693g CO, D2693h CO.

Discussion.—The Idaho specimens are closely similar to British specimens of *G. hincksii* in rhabdosome width, rate of rhabdosome widening, thecal spacing, character of the apertural spines, and in features of the proximal end. Closely spaced thecae in the proximal region, maximum rhabdosome width, and relative robustness of apertural spines are characters that may be used to distinguish *G. hincksii* from most other glossograptids.

Genus PARAGLOSSOGRAPTUS Hsu

Members of the genus *Paraglossograptus* are similar to those in the genus *Glossograptus* in many characters, but paraglossograptids have a lacinia by which they may be distinguished from glossograptids.

Paraglossograptus? sp.
Plate 6, figure 10

Two specimens found in the collections are incomplete and are abraded but have characters suggestive of *Paraglossograptus.* The specimens are 10 to 12 mm long and parallel sided for most of their length. They are 1.3 to 1.5 mm wide in the proximal part, across the first thecal pair. They widen to about 3 mm in 5 mm from the proximal end, and to a maximum of about 4 mm in 7 mm to 8 mm from the proximal end.

Thecae number 11 to 12 in 10 mm. They are orthograptid in aspect and their apertures are spinose. Thecal apertural spines appear to bifurcate, and the bifurcations join to form an apparent lacinia.

Figured specimen.—USNM 241145.

Occurrence.—USGS colln. D2693i CO.

Discussion.—The presence of a lacinia formed relatively similarly to that in species of *Paraglossograptus,* and the presence of orthograptid thecae that bear spines at their apertures suggest that the specimens are paraglossograptids. Indistinct and incomplete preservation makes precise identification uncertain.

Family CRYPTOGRAPTIDAE Hadding, 1915, emend. Bulman, 1970

Only one genus is currently recognized within the family Cryptograptidae.

Genus CRYPTOGRAPTUS Lapworth, 1880

Cryptograptus rhabdosomes are characteristically essentially parallel sided. Spines, if present, are borne only on the first two thecae.

Cryptograptus schaferi Lapworth, 1880
Text figure 13

Cryptograptus tricornis var. *schaferi* Lapworth, 1880, Annals and Mag. Nat. History, v. 5, 5th ser., pl. 5, figs. 28a, b.

Cryptograptus tricornis schaferi Lapworth. Elles and Wood, 1908, Palaeontographical Soc., v. 62, pt. 7, p. 299, pl. 32, figs. 13a–c.

Cryptograptus schaferi Lapworth. Harris and Thomas, 1935, Royal Soc. Victoria Proc., v. 47, new ser., pt. 2, p. 304, fig. 3, nos. 11, 12.

Cryptograptus schaferi Lapworth. Ross and Berry, 1963, U.S. Geol. Survey Bull. 1134, p. 96–97, pl. 5, figs. 28, 29.

The rhabdosomes are 10 to 14 mm long. They are 1.5 to 1.6 mm wide across the first pair of thecal apertures, and they remain essentially parallel sided for the remainder of their extent; or they may narrow slightly in the distal 5 mm.

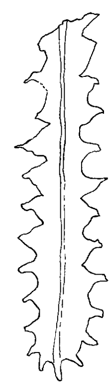

FIGURE 13.—*Cryptograptus schaferi* Lapworth. × 5. USNM 241146. USGS colln. D2693h CO. Dashed where reconstructed.

Thecae number 6½ to 7 in the proximal 5 mm and 11 to 13 in 10 mm. Thecal ventral walls are curved, their inner parts being inclined at a 40° to 50° angle to the rhabdosome axis and their outer parts being inclined at a 55° to 70° angle to the rhabdosome axis. The apertural margins appear to be strengthened by lists. That part of the ventral margin that joins the ventral thecal wall appears to be drawn outward into small but distinct flange.

The first two thecae appear to have grown downward for the greater part of their length, but their distal parts curve to become directed upward. A tubular virgula is present.

Figured specimen.—USNM 241146.

Occurrence.—USGS collns. D2544 CO, D2550 CO, D2693c CO, D2639h CO, D2693k CO.

Discussion.—The species *C. schaferi* is characterized by its essentially parallel sided aspect, its short flanges on the apertural lips, and the absence of spines. The Idaho specimens at hand are relatively incompletely preserved, but the typical characters may be observed.

Suborder DIPLOGRAPTINA Lapworth, 1880, emend. Bulman, 1970
Family DIPLOGRAPTIDAE Lapworth, 1873
Genus DIPLOGRAPTUS M'Coy, 1850

Members of the genus *Diplograptus* have biserial scandent rhabdosomes in which proximal-region thecae are strongly sigmoidally curved and distal-region thecae are essentially straight.

Diplograptus decoratus multus Ross and Berry, 1963
Not illustrated

Diplograptus decoratus var. *multus* Ross and Berry, 1963, U.S. Geol. Survey Bull. 1134, p. 135-136, pl. 10, figs. 9, 10, 15.

The rhabdosomes are as much as 28 mm long. They characteristically have a markedly tapered proximal part and a relatively long distal part that may be parallel sided but that tapers gently distally in most rhabdosomes. The rhabdosomes are 1.0 to 1.3 mm wide across the first thecal apertures. They widen to 1.5 to 1.8 mm 5 mm from the first thecal apertures, to 2.3 to 2.6 mm 10 mm from the first thecal apertures, to a maximum of 3.1 to 3.8 mm 13 to 15 mm from the first thecal apertures. Most rhabdosomes narrow slightly distally from about 15 mm from the proximal end.

Thecae number 14 to 16 in the proximal 10 mm and 12 to 14 in the distal part of the rhabdosomes. The proximal 8 to 12 pairs of thecae are strongly geniculate and have an amplexograptid aspect. Apertures of these thecae are in semicircular excavations that occupy about one-fourth to one-third the width of the rhabdosome. Thecae distal from those having amplexograptid aspect have gently curved free ventral walls and are glyptograptid in aspect. Thecae in the distal part of the rhabdosome have almost straight ventral walls and are essentially orthograptid in aspect.

Siculae have a stout virgella. A relatively wide virgula is present; but most specimens are incomplete, and the virgula is not preserved.

Figured specimen.—None illustrated.

Occurrence.—D2508 CO, D2518 CO, D2693h CO, D2693l CO.

Discussion.—The Idaho specimens are closely similar to typical specimens of the subspecies that were collected in Nevada (Ross and Berry, 1963, p. 136) in most characters. Thecal spacing in the proximal part of the Idaho rhabdosomes may be slightly closer, and some of the Idaho specimens widen to slightly greater widths than do typical specimens from Nevada. The essential characters of maximum rhabdosome width of at least 3 mm and relatively close thecal spacing throughout the rhabdosome clearly indicate the relationship of the Idaho specimens in the subspecies *multus*. Closeness of thecal spacing distinguishes North American subspecies of *D. decoratus* from Australian.

Most of the specimens for *D. decoratus multus* found in the present study are fragmentary and highly compressed. Detailed measurements could be obtained from a relatively few of the many specimens found. Specimens or fragmentary specimens of *D. decoratus multus* are relatively common in the stratigraphically upper part of the sequence examined.

Genus AMPLEXOGRAPTUS Elles and Wood, 1907

Amplexograptids have strongly geniculate thecae, relatively deep apertural excavations, and, commonly, a thickening or selvage along the infragenicular wall and the aperture. The supragenicular part of the thecal wall commonly is inclined at an angle to the rhabdosome axis.

Amplexograptus? sp.
Plate 6, figure 2

Two rhabdosome fragments are present in the collections. The longer is 12.5 mm. The rhabdosomes are parallel sided and about 3.0 mm wide throughout their length. Proximal parts were not preserved.

Thecae appear to be strongly geniculate. They number 13 in 10 mm. apertural margins are straight and approximately horizontal. The geniculum is rounded. The genicular wall is rounded and appears to be nearly parallel with the rhabdosome axis. The infrageniculum is curved, but the greater part of it is oriented at about a 60° to 75° angle to the rhabdosome axis. A selvage appears to thicken the infragenicular wall, although it is not clear in most thecae whether it is present or not because the periderm has been distorted during preservation. Apertural excavations are 0.8 to 1.0 mm deep and 0.4 to 0.6 mm wide at ventral sides of the rhabdosome.

Figured specimen.—USNM 241147.

Occurrence.—USGS collns. D2518 CO, D2597 CO.

Discussion.—The rhabdosomes are clearly biserial and appear to have the essential thecal characteristics of *Amplexograptus*. The specimens are incomplete rhabdosomes and somewhat distorted, making determination of most characters uncertain.

Genus GLYPTOGRAPTUS Lapworth, 1873

Glyptograptids are characterized by thecae that have relatively gentle sigmoidal curvature. Curvature may be more pronounced in proximal-region thecae than in distal.

Glyptograptus austrodentatus americanus Bulman, 1963
Plate 6, figures 4, 5, 7; text figure 14

Glyptograptus cf. *G. austrodentatus* Berry, 1960, Texas Univ. Bur. Econ. Geol. Pub. 6005, p. 87, pl. 13, figs. 2-3.
Glyptograptus austrodentatus var. *americanus* Bulman, 1963, Palaeontology, v. 6, pt. 4, p. 683-684, pl. 97, figs. 18, 19, text figs. 2e-i, 3, 9.

The rhabdosomes have an essentially parallel sided aspect. They are as much as 16 mm long. Rhabdosome width is 1.3 to 1.6 mm across the first thecal aperture and increases to 1.9 to 2.0 mm 3 to 5 mm from the first thecal aperture; it commonly is that width throughout the remainder of the extent. Some rhabdosomes widen to about 2.1 to 2.2 mm 10 to 12 mm from the first thecal aperture and are that width for the remainder of their extent. Most rhabdosomes widen to a maximum width of 1.9 m within the first 5 mm and remain parallel sided throughout.

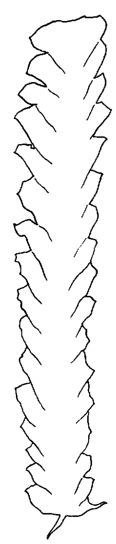

FIGURE 14.—*Glyptograptus austrodentatus americanus* Bulman. Drawing from photograph showing rhabdosome width and thecal characters. Proximal-region thecae have curved free ventral walls as in type of *G. austrodentatus austrodentatus* Harris and Keble. × 5. USNM 241151. USGS colln. D2693c CO.

Thecae number 6 to 7 in the proximal 5 mm and 5 to 5½ in 5 mm in the distal parts of the longest rhabdosomes. The first two thecae are markedly smaller than the others, and a small subapertural spine is present on them; whereas no other thecae bear spines. The second, third, and, in some specimens, fourth pair of thecae have a relatively pronounced genicular curve one-third to one-half the length of the metatheca, with the result that the free ventral walls of these thecae are markedly curved. Free ventral walls of thecae distal from the third or fourth thecal pair are gently curved to almost straight. Free ventral thecal walls in thecae in the distal part of the rhabdosome are essentially straight. Thecal overlap in the second, third, and fourth pair of thecae is one-half to three-fifths, but overlap is less in thecae distal from the fourth thecal pair. Overlap may be as little as one-third in thecae in the distal part of the rhabdosome. That part of the free ventral wall that joins the aperture curves slightly inward to give the thecal apertures a slight introverted aspect and to form a ventral apertural lip. Ventral apertural lips are relatively marked in some specimens, but they are relatively slight in most.

Siculae appear to be about 2 mm long. The first two thecae are arranged subsymmetrically about the sicula, and their free ventral walls are gently rounded. A small virgella descends from the sicula aperture. A complete median septum is present. It may be slightly undulating.

Figured specimens.—USNM 241148, 241149, 241150, 241151.

Occurrence.—USGS collns. D2502 CO, D2693a CO, D2693c CO, D2693d CO, D2693g CO.

Discussion.—The Idaho specimens are similar to typical specimens from the Marathon region, Texas, in most characters. They differ slightly from Texas specimens in not having as prominent ventral apertural lips and in the presence of more pronounced geniculation in the second, third, and fourth pairs of thecae. The first thecal pair appears to be slightly more symmetrically arrayed in the Idaho specimens than it is in the Texas specimens. Some of the Idaho specimens may widen to slightly greater maximum width than the Texas specimens, but maximum width seen may be a result of differences in preservation. The Texas specimens are commonly preserved partly round in limestone; whereas the Idaho specimens are compressed and preserved in argillite.

The presence of relatively geniculate thecae in the proximal part of the rhabdosome and the almost symmetrical arrangement of the first thecal pair are diagnostic characters of *G. austrodentatus austrodentatus*. Their presence in the Idaho specimens of *G. austrodentatus americanus* suggests that individuals in the Idaho populations of *G. austrodentatus americanus* may have interbred with members of the local populations of *G. austrodentatus austrodentatus*, or that the Idaho populations of *G. austrodentatus americanus* were developing from populations of *G. austrodentatus austrodentatus*.

The Idaho specimens of *G. austrodentatus americanus* are considered part of the subspecies *americanus* because they have the rhabdosome width and thecal spacing of the subspecies *americanus*. Most of the Idaho specimens have more prominent ventral apertural processes than do members of the subspecies *austrodentatus.*

Glyptograptus austrodentatus austrodentatus Harris and Keble, 1932.
Plate 6, figure 3

Diplograptus (Glyptograptus) austrodentatus Harris and Keble, 1932, Royal Soc. Victoria Proc., v. 44, new ser., pt. 1, p. 25–48.
Diplograptus (Glyptograptus) austrodentatus Harris and Keble. Harris and Thomas, 1935, Royal Soc. Victoria Proc., v. 47, new ser., pt. 2, p. 295–296, fig. 3, nos. 1-5.
Glyptograptus austrodentatus austrodentatus Harris and Keble. Bulman, 1963, Palaeontology, v. 6, pt. 4, pl. 97, figs. 6-9, 12, text fig. 6.

The rhabdosomes are short, commonly 5 to 8 m long, and parallel sided. They widen from 1.3 to 1.5 mm across the first thecal apertures to a maximum of 1.5 to 1.6 mm at the second or third pair of thecal apertures, and they are that width throughout the remainder of their extent.

Thecae number 6½ to 7 in the proximal 5 mm. The first pair of thecae are small, slender, gently rounded, and symmetrically arranged about the sicula. Each bears a subapertural spine. Their arrangement gives the rhabdosome a rounded aspect at the proximal end. The second, third, fourth, and, in some specimens, fifth through seventh pair of thecae are significantly geniculate. The geniculation gives the free ventral walls a rounded aspect, and some thecae appear to have a distinct geniculum. Although geniculation is pronounced among thecae in the proximal part of the rhabdosome, it does occur in some thecae distal from the sixth or seventh thecal pair. Thecal geniculation is, however, commonly less pronounced in thecae distal from the sixth or seventh pair. Thecae in the distal part of the rhabdosomes commonly have gently curved free ventral walls. Thecal overlap is about one-half, being somewhat more than that among thecae in the proximal part of the rhabdosome and slightly less in thecae in the distal part of the rhabdosome. Some thecal apertures are slightly introverted.

A short virgella descends from the sicula aperture. A complete median septum is present.

Figured specimen.—USNM 241152.

Occurrence.—USGS collns. D2503 CO, D2693a CO, D2693c CO, D2693d CO, D2693f CO, D2693g CO.

Discussion.—The specimens assigned to the subspecies *G. austrodentatus austrodentatus* are characterized by their maximum width of 1.5 to 1.6 mm which is attained by the second thecal pair in most specimens and by the pronounced geniculation of thecae in the proximal part of the rhabdosome. Symmetrical arrangement of the first thecal pair and the consequent rounded aspect of the proximal end of the rhabdosme is also characteristic.

Although the majority of individuals of *G. austrodentatus* in the Idaho collections appear to be members of the subspecies *americanus,* a few having the characters described above are considered members of the subspecies *austrodentatus.* Interestingly, therefore, the ranges in geographic distribution of the two subspecies seem to have overlapped in the area now Idaho. Many of the individuals considered members of the subspecies *americanus* have pronounced geniculation in proximal-region thecae and nearly symmetrical arrangement of the first thecal pair, suggesting that interbreeding may have taken place between members of the two subspecies and colonies having characters of both subspecies developed.

Glyptograptus cf. G. euglyphus Lapworth, 1877
Plate 6, figures 8, 9

The rhabdosomes are slender and have a tapered aspect. They are 0.5 to 0.6 mm wide across the first thecal aperture. They widen to 1.2 to 1.5 mm 5 mm from the first thecal aperture, to 1.7 to 2.0 mm 10 mm from that position, to their maximum of 1.9 to 2.2 mm 12 to 15 mm from that position. The longest rhabdosomes observed are 17 mm and incomplete.

The thecae markedly alternate. Thecal spacing is 6 to 7 in the proximal 5 mm, 11½ to 12 in the proximal 10 mm, and 5 in 5 mm in the distal part of the longest rhabdosomes. The proximal one or two pairs of thecae are relatively smaller than the others and their free ventral walls are more curved than in thecae distal from them. Free ventral walls in thecae in medial and distal parts of the rhabdosome are slightly curved. Thecal overlap is about one-half, and the thecae in medial and distal parts of the rhabdosome are 4 to 4½ times as long as they are wide. The thecae are inclined to the rhabdosome axis at an angle of 22° to 30°.

A short virgella descends from the sicula. The first theca in some rhabdosomes appears to bear a minute subapertural spine.

Figured specimens.—USNM 241153, 241154.

Occurrence.—USGS colln. D26931 CO.

Discussion.—The Idaho rhabdosomes appear to be closely similar to *G. euglyphus* Lapworth (1877) (see also Elles and Wood, 1907, p. 252, pl. 31, figs. 2a–d) in most characters. Thecal spacing in the Idaho specimens is slightly closer in the proximal region, and small spines may be present on the first theca. The Idaho specimens are similar to specimens described as *Diplograptus (Glyptograptus)* cf. *euglyphus* (Lapworth) by Harris and Thomas (1935, p. 297–298, fig. 3, nos. 39–41) from Victoria, Australia. Indeed, thecal spacing, maximum rhabdosome width, and rate of rhabdosome widening of the Idaho specimens are essentially identical to some specimens examined by the author of *Glyptograptus* cf. *G. euglyphus* identified by Harris and Thomas from Victoria localities.

GRAPTOLITE COLLECTIONS

The Ordovician ages given in this report are from the graptolite zones of Berry (1960, 1976). The correlation of zone names and ages with the zones of Elles and Wood (1901–14) are shown in table 4.

A listing of 116 fossil collections follows. These fossil collection sites are shown on plate 1 and are described in detail in the following pages.

ORDOVICIAN GRAPTOLITE COLLECTIONS

USGS colln. D2236 CO. Phi Kappa Formation, collected from about 300 feet of section by C. M. Tchanz in 1970. Little Fall Creek, altitude 10,200 ft. UTM (Universal Transverse Mercator) grid, zone 11: E. 718,620 m, N. 4,860,950 m. Rock Roll Canyon 7½ min. quadrangle, Idaho. See also colln. D2521 CO.

Dicellograptus divaricatus bicurvatus Ruedemann
Dicellograptus cf. *D. sextaus* (J. Hall)
Dicranograptus spinifer Elles
Cryptograptus tricornis Carruthers
Nemagraptus sp.
Climacograptus bicornis (J. Hall)
C. eximius Ruedemann
Orthograptus sp.
Age: Zone 12.

USGS colln. D2237 CO. Phi Kappa Formation, on ridge between Little Fall Creek and Trail Creek, halfway to saddle. Collected by C. M. Tchanz in 1970. UTM grid, zone 11: E. 718,460 m, N. 4,860,710 m. Rock Roll Canyon quadrangle, Idaho.

Preservation of graptolites very poor. *Climacograptus* and *Orthograptus* may be present.
Age: In range of zones 9–16.

USGS colln. D2238 CO. Phi Kappa Formation, in white-weathering black shale. Collected by C. M. Tchanz in 1970. UTM grid, zone 11: E. 718,500 m, N. 4,861,360 m. Rock Roll Canyon quadrangle, Idaho.

Dicranograptus nicholsoni var. *whitianus* (Miller)
Cryptograptus tricornis (Carruthers)
Pseudoclimacograptus scharenbergi Lapworth
Climacograptus phyllophorus Gurley
Glyptograptus cf. *G. teretiusculus*
Age: Zone 12.

USGS colln. D2239 CO. Phi Kappa Formation, along Trail Creek road. UTM grid, zone 11: E. 720,520 m, N. 4,854,970 m. Rock Roll Canyon quadrangle, Idaho.

Holograptus? sp. or *Ptilograptus*? sp.
Phyllograptus sp.
Tetragraptus sp.
Didymograptus? sp. (fragments)
Isograptus sp.
Dicellograptus cf. *D. intortus* Lapworth
Climacograptus cf. *C. eximius* Ruedemann
Orthograptus? cf. *O. whitfieldi* (J. Hall)
Age: A mixed collection; partly zone 8 and partly zone 12.

USGS colln. D2501 CO. Phi Kappa Formation, altitude 9,200 ft., on southern tributary of Little Fall Creek, UTM grid, zone 11: E. 719,185 m, N. 4,859,445 m. Rock Roll Canyon quadrangle, Idaho.

Clonograptus sp.
Fragments of other anisograptids(?)
Age: Probably in span of zones 2–4.

USGS colln. D2502 CO. Phi Kappa Formation, altitude 9,207 ft., UTM grid, zone 11: E. 719,185 m, N. 4,859,420 m. Rock Roll Canyon quadrangle, Idaho.

Didymograptus sp.
Isograptus victoriae lunatus Harris?
Glyptograptus austrodentatus var. *americanus* Bulman
Age: Zone 8.

USGS colln. D2503 CO. Phi Kappa Formation, altitude 9,226 ft., UTM grid, zone 11: E. 719,185 m, N. 4,859,400 m. Rock Roll Canyon quadrangle, Idaho.

Didymograptus sp. (cf. *D. cognatus* Harris and Thomas)
Tetragraptus cf. *T. quadribrachiatus* (J. Hall)
Isograptus victoriae victoriae Harris
Glyptograptus austrodentatus cf. var. *austrodentatus* Harris and Keble
Age: Zone 8.

USGS colln. D2504a CO. Phi Kappa Formation, altitude 9,253 ft., UTM grid, zone 11: E. 719,170 m, N. 4,859,300 m. Rock Roll Canyon quadrangle, Idaho

Didymograptus? sp.
Pseudisograptus dumosus Harris?
Glyptograptus cf. *G. austrodentatus*? subsp.?
Age: Probably in span of zones 8–9.

USGS colln. D2504b CO. Phi Kappa Formation, altitude 9,315 ft., UTM grid, zone 11: E. 719,150 m, N. 4,859,355 m. Rock Roll Canyon quadrangle, Idaho.

Dichograptus sp.
Didymograptus sp.
Holmograptus (Ruedemann)
Cardiograptus sp.
Cryptograptus tricornis (Carruthers)
Climacograptus?
Diplograptus decoratus var.?
Age: Zone 9.

USGS colln. D2508 CO. Phi Kappa Formation, altitude 9,553 ft., UTM grid, zone 11: E. 718,995 m, N. 4,859,240 m. Rock Roll Canyon quadrangle, Idaho.

Cryptograptus scaferi?
Climacograptus? sp.
Glyptograptus? sp.
Diplograptus decoratus var. *multus* Ross and Berry?
Age: Probably zone 9 or 10.

USGS colln. D2509 CO. Phi Kappa Formation, altitude UTM grid, zone 11: E. 718, 965 m, N. 4,859,220 m. Rock Roll Canyon quadrangle, Idaho.

Dicellograptus? sp.
Climacograptus? sp.
Diplograptus sp.
Age: Middle–Late Ordovician.

TABLE 4.— *Comparison of Ordovician graptlite zones of Berry (1960, 1976) for the Western United States with zones of Elles and Wood (1901-14) for the British Isles*

[Suggested equivalences only approximate]

System	Series	British stage	Zones of Elles and Wood, 1960-14		Zones of Berry, 1960 and 1976 (also, Barnes and others, 1976)	
ORDOVICIAN	Upper	Ashgillian	15	*Dicellograptus anceps*	*Dicellograptus complanatus*	15
			14	*Dicellograptus complanatus*		
		Caradocian	13	*Pleurograptus linearis*	*Orthograptus quadrimucronatus*	14
			12	*Dicranograptus clingani*		
	—?— Middle		11	*Climacograptus wilsoni*	*Orthograptus truncatus* var. *intermedius*	13
			10	*Climacograptus peltifer* and *Diplograptus multidens*	*Climacograptus bicornis*	12
		Llandeilian	9	*Nemagraptus gracilis*	*Nemagraptus gracilis*	11
			8	*Glyptograptus teretiusculus*	*Glyptograptus* cf. *teretiusculus*	10
		Llanvirnian	7	*Didymograptus murchisoni*	*Paraglossograptus etheridgei*	9
			6	*Didymograptus bifidus*	*Isograptus victoriae* / *Didymograptus bifidus*	8 / 7
	Lower	Arenigian	5	*Didymograptus hirundo*	*Didymograptus protobifidus*	6
			4	*Didymograptus extensus*	*Tetragraptus fruiticosus*: 3- and 4-branch	5
					Tetragraptus fruiticosus: 4-branch	4
			3	*Dichograptus*	*Tetragraptus approximatus*	3
		Late Tremadocian	3	*Bryograptus*	*Clonograptus-Adelograptus*	2
			1	*Dictyonema*	*Anisograptus-Staurograptus*	1

USGS colln. D2510 CO. Phi Kappa Formation, highest beds beneath brown siltstone, altitude 9,610 ft., UTM grid, zone 11: E. 718,995 m, N. 4,859,410 m. Rock Roll Canyon quadrangle, Idaho.

Climacograptus? sp.
Orthograptus cf. *O. quadrimucronatus* (J. Hall)
Age: Probably zone 14.

USGS colln. D2511 CO. Phi Kappa Formation, along west side of Trail Creek, altitude 8,035 ft., UTM grid, zone 11: E. 716,970 m, N. 4,859,490 m. Rock Roll Canyon quadrangle, Idaho.

Leptograptid dicellograptid fragments
Age: Middle or Late Ordovician.

USGS colln. D2512 CO. Phi Kappa Formation, altitude 8,065 ft., UTM grid, zone 11: E. 716,950 m, N. 4,859,460 m. Rock Roll Canyon quadrangle, Idaho.

Dicellograptus ornatus minor Toghill
Climacograptus hastatus americanus Ruedemann
Climacograptus supernus Elles and Wood
Glyptograptus altus Ross and Berry
Orthograptus truncatus abbreviatus Elles and Wood
Arachniograptus? sp.
Age: Zone 15.

USGS colln. D2513 CO. Phi Kappa Formation, altitude 8,135 ft., UTM grid, zone 11: E. 716,840 m, N. 4,859,240 m. Rock Roll Canyon quadrangle, Idaho.

Didymograptus sagitticaulus Gurley?
Climacograptus bicornis (J. Hall)
Climacograptus phyllophorus Gurley
Glyptograptus teretiusculus (Hisinger)
Orthograptus cf. *O. whitfieldi* (J. Hall)
Orthograptus? sp.
Age: Zone 12.

USGS colln. D2514 CO. Phi Kappa Formation, altitude 8,000 ft., UTM grid, zone 11: E. 716,960 m, N. 4,859,315 m. Rock Roll Canyon quadrangle, Idaho.

Climacograptus? sp.
Glyptograptus? sp.
Age: Middle-Late Ordovician.

USGS colln. D2515 CO. Phi Kappa Formation, south of Park Creek, altitude 7,820 ft., UTM grid, zone 11: E. 720,310 m, N. 4,856,910 m. Rock Roll Canyon quadrangle, Idaho.

Dicellograptus sp. (?*D. elegans* Carruthers)
Climacograptus sp.
Orthograptus sp. (of the *O. truncatus* type)
Orthograptus sp. (of the *O. quadrimucronatus* type?)
Orthograptus cf. *O. calcaratus* (Lapworth)
Age: In span of zones 13-14.

USGS colln. D2516 CO. Phi Kappa Formation, above Park and Summit Creeks, altitude 8,200 ft., UTM grid, zone 11: E. 720,110 m, N. 4,856,750 m. Rock Roll Canyon quadrangle, Idaho.

Dichograptid fragments
Tetragraptus serra (Brogniart)
Phyllograptus sp.
Cardiograptus crawfordi Harris
Age: In span of zones 8-9. See also collection D2590 CO.

USGS colln. D2516a CO, 15 ft. above D2516 CO.

Pseudobryograptid
Pseudobryograptus incertus (Harris and Thomas)
Tetragraptus amii Lapworth
Pseudisograptus manubriatus (T. S. Hall)
Pseudisograptus dumosus (Harris)
Pseudisograptid?
Isograptus caduceus australis Cooper
Isograptus caduceus imitatus Harris
Cardiograptus morsus Harris and Keble
Glossograptus hincksii (Hopkinson)
Cryptograptus sp.
Age: In span of zones 8-9—probably zone 8.

USGS colln. D2516b CO, 16 ft. above D2516 CO.

Pseudobryograptus incertus (Harris and Thomas)?
Tetragraptus sp.
Phyllograptus sp.
Pseudisograptus dumosus Harris
Pseudisograptus manubriatus (T. S. Hall)
Glossograptus sp.
Age: In span of zones 8-9.

USGS colln. D2516c CO, 22 ft. above D2516 CO.

Phyllograptus sp.
Didymograptus sp. (cf. *D. cuspidatus* Ruedemann)
Isograptus victoriae victoriae Harris
Glossograptus cf. *G. acanthus* Elles and Wood
Age: In span of zones 8-9.

USGS colln. D2518 CO. Phi Kappa Formation. Altitude 10,120 ft., UTM grid, zone 11: E. 718,480 m, N. 4,860,680 m. Rock Roll Canyon quadrangle, Idaho.

Uniserial dichograptid stipes
Cryptograptus sp.
Pseudoclimacograptus scharenbergi Lapworth
Amplexograptus? sp.
Glyptograptus sp.
Diplograptus decoratus multus Ross and Berry
Several undetermined biserial taxa
Age: Probably zones 9-10.

USGS colln. D2519 CO. Phi Kappa Formation, UTM grid, zone 11: E. 718,940 m; N. 4,861,375 m. Rock Canyon quadrangle, Idaho.

A great variety of dichograptids. May include *Dichograptus, Clonograptus.* A dichograptid having stipes like those of *Kinnegraptus.*
Adelograptus? sp.
Age: Probably zones 2–4.

USGS colln. D2520 CO. Phi Kappa Formation, altitude 9,860 ft., UTM grid, zone 11: E. 718,980 m; N. 4,861,270 m. Rock Roll Canyon quadrangle, Idaho.

Clonograptus? sp.
Age: Probably zones 2–4.

USGS colln. D2521 CO. Phi Kappa Formation, altitude 10,190 ft., UTM grid, zone 11: E. 718,620 m, N. 4,860,950 m. Rock Roll Canyon quadrangle, Idaho.

Cryptograptus tricornis (Carruthers)
Dicranograptus contortus Ruedemann
Dicranograptus ramosus
Dicellograptus sp.
Climacograptus bicornis J. Hall
Orthograptus calcaratus var. *acutus* Elles and Wood
Hallograptus sp.
Retiograptus? sp.
Age: Zone 12.

USGS colln. D2522 CO. Phi Kappa Formation, altitude 10,080 ft., UTM grid, zone 11: E. 718,120 m, N. 4,861,080 m. Rock Roll Canyon quadrangle, Idaho.

Climacograptus sp.
Orthograptus of the *O. truncatus* (Lapworth) type
O. of the *O. calcaratus* (Lapworth) type
O. quadrimucronatus (J. Hall)
Age: Zones 13–14.

USGS colln. D2523 CO. Phi Kappa Formation, altitude 9,700 ft., UTM grid, zone 11: E. 718,200 m, N. 4,861,400 m. Meridian Peak 7½ min. quadrangle, Idaho.

Phyllograptus anna J. Hall
Isograptus of the *I. victoriae* group
Pseudisograptus cf. *P. manubriatus* (T. S. Hall)
Holmograptus spinosus (Ruedemann)
Glyptograptus cf. *G. austrodentatus americanus* Bulman
Age: Zones 8–9.

USGS colln. D2524 CO. Phi Kappa Formation, altitude 9,720 ft., at head of main fork of Big Fall Creek. UTM grid, zone 11: E. 719,750 m, N. 4,862,220 m. Meridian Peak quadrangle, Idaho.

Dicellograptus intortus Lapworth
Climacograptus sp.
Age: Probably zones 11–12.

USGS colln. D2525 CO. Phi Kappa Formation, east side of peak 10350, altitude 9,800 ft., UTM grid, zone 11: E. 719,865 m, N. 4,862,065 m. Meridian Peak quadrangle, Idaho.

Tristichograptus sp.
Isograptus sp.
Cardiograptus? sp.
Climacograptus sp.
Glyptograptus? sp.
Age: Probably zones 8–9.

USGS colln. D2526 CO. Phi Kappa Formation, west of divide north of peak 10214, altitude 10,330 ft., UTM grid, zone 11: E. 718,460 m, N. 4,860,750 m. Rock Roll Canyon quadrangle, Idaho.

Biserial specimen but not *Climacograptus.* Seems to be meshwork or have lacinia.
Biserial scandent forms
Glyptograptus? sp.
Age: Preservation is poor—Middle–Late Ordovician.

USGS colln. D2527 CO. Phi Kappa Formation, across creek from type section of Trail Creek Formation, altitude 8,060 ft., UTM grid, zone 11: E. 717,070 m, N. 4,859,550 m. Rock Roll Canyon quadrangle, Idaho. All graptolites poorly preserved and sheared parallel to bedding.

Corynoides sp.
Leptograptid
Climacograptus sp.
Glyptograptus? sp.
Orthograptus? sp.
Age: In span of zones 11–13.

USGS colln. D2528 CO. Phi Kappa Formation, on slope east of Trail Creek, altitude 8,680 ft., UTM grid, zone 11: E. 717,600 m, N. 4,859,440 m. Rock Roll Canyon quadrangle, Idaho.

Cryptograptus sp.
Climacograptus bicornis J. Hall
Diplograptus? sp.
Genera probably include *Climacograptus* (a small species) and *Orthograptus*? Preservation poor.
Age: Probably zone 12.

USGS colln. D2529 CO. Phi Kappa Formation, on slope east of Trail Creek, due west of peak 10244, altitude 9,045 ft., UTM grid, zone 11: E. 717,830 m, N. 4,859,860 m. Rock Roll Canyon quadrangle, Idaho.

Climacograptus sp. (possibly *C. raricaudatus* Ross and Berry or even *C. typicalis* J. Hall)
Climacograptus sp.
Pseudoclimacograptus scharenbergi (Lapworth)?
Age: Possibly zone 12, 13, or 14.

USGS colln. D2530a CO. Phi Kappa Formation, on southwest-facing slope, northwest of peak 10244. Altitude 9,155 ft., UTM grid, zone 11: E. 717,820 m, N. 4,860,200 m. Rock Roll Canyon quadrangle, Idaho.

Leptograptus? sp.
Dicranograptus cf. *D. ramosus longicaulis* Elles and Wood
Climacograptus sp. (probably *Climacograptus spiniferus* Ruedemann)
Climacograptus sp. (proximal spines, but not *C. hastatus)*
Orthograptus sp. (possibly *O. quadrimucronatus*)
Orthograptus sp. (spinose, of the *O. quadrimucronatus* group)
Age: Probably zone 13 (upper part).

USGS colln. D2530b CO. Same locality as D2530a.

Dicellograptus divaricatus (Hall)
Dicellograptus sextans J. Hall
Dicranograptus ramosus (J. Hall)
Glossograptus sp.
Climacograptus peltifer Lapworth
Climacograptus cf. *C. caudatus* Lapworth
Age: Zone 12.

USGS colln. D2531 CO. Phi Kappa Formation, altitude 9,080 ft., west-southwest from peak 10214. UTM grid, zone 11: E. 717,700 m, N. 4,860,230 m. Rock Roll Canyon quadrangle, Idaho.

Corynoides sp.
Dicranograptus cf. *nicholsoni* var. *geniculatus* Ruedemann and Decker
Cryptograptus sp.
Climacograptus sp. (small species)
Glyptograptus? sp.
Orthograptus sp. of *O. quadrimucronatus* group?
Age: Probably zone 13.

USGS colln. D2532 CO. Phi Kappa Formation, altitude 8,740 ft., east of Trail Creek. UTM grid., zone 11: E. 717,520 m, N. 4,860,130 m. Rock Roll Canyon quadrangle, Idaho.

Dicellograptus cf. *D. forchammeri flexuosus* Lapworth
Climacograptus cf. *C. minimus* (Carruthers)
Age: Probably zone 14.

The following collections are in a more southerly area near Park Creek:

USGS colln. D2533 CO. Phi Kappa Formation, in Basin Gulch, altitude 7,240 ft., UTM grid, zone 11: E. 720,000 m, N. 4,854,410 m. Rock Roll Canyon quadrangle, Idaho.

Climacograptus cf. *eximius* var. *pygmaeus* Ruedemann
Age: Probably zone 12.

USGS colln. D2534 CO. Phi Kappa Formation, along Trail Creek, east side above falls, altitude 7,440 ft., UTM grid, zone 11: E. 719,475 m, N. 4,855,580 m. Rock Roll Canyon quadrangle, Idaho.

Dicellograptus sp.
Climacograptus (very small species)
Glyptograptus? sp.
Diplograptus sp.
Orthoretiolites? sp.
Age: Probably zone 13—but in span of zones 12–14.

USGS colln. D2535 CO. Phi Kappa Formation, 45 ft. above and west of Trail Creek, altitude 7,800 ft., UTM grid, zone 11: E. 717,545 m, N. 4,857,135 m. Rock Roll Canyon quadrangle, Idaho.

Dicranograptus cf. *ramosus longicaulis* Elles and Wood
Climacograptus supernus Elles and Wood
Glyptograptus sp.
Orthograptus? sp.
Age: Probably zone 13.

USGS colln. D2536 CO. Formation uncertain, northeast side of Trail Creek, altitude 7,715 ft., UTM grid, zone 11: E. 718,390 m, N. 4,856,820 m. Rock Roll Canyon quadrangle, Idaho.

Climacograptus cf. *C. spiniferus* Ruedemann
Climacograptus sp.
Diplograptus? sp.
Age: Probably zone 13.

USGS colln. D2537 CO. Phi Kappa Formation, on northeast side of Trail Creek, altitude 7,720 ft., UTM grid, zone 11: E. 718,120 m. N. 4,857,025 m. Rock Roll Canyon quadrangle, Idaho.

Glyptograptus (possibly *G. teretiusculus* (Hisinger))
Phyllograptus sp.
Didymograptus (pendent species)?
Diplograptus? sp.
Age: Probably in range of zones 9–10.

The following collections came from the drainage of Little Fall Creek.

USGS colln. D2540 CO. Phi Kappa Formation, altitude 9,450 ft., UTM grid, zone 11: E. 719,300, N. 4,859,190 m. Rock Roll Canyon quadrangle, Idaho.

Dichograptid or Anisograptid scraps. Preservation very poor.
Age: Early Ordovician.

USGS colln. D2541 CO. Phi Kappa Formation, northeast of peak 10227 on northwest side of ridge. Altitude 9,720 ft., UTM grid, zone 11: E. 719,400 m, N. 4,859,080 m. Rock Roll Canyon quadrangle, Idaho.

Undetermined dichograptid stipes
Tetragraptus quadribrachiatus? (J. Hall)
Glossograptus sp.
Age: Probably zone 9.

USGS colln. D2542 CO. Phi Kappa Formation, on ridge crest northeast of peak 10227, altitude 9,840, UTM grid, zone 11: E. 719,350 m, N. 4,858,980 m. Rock Roll Canyon quadrangle, Idaho.

Dicranograptus nicholsoni whitianus (Miller)
Climacograptus spiniferus Ruedemann
Climacograptus cf. *C. typicalis* J. Hall
Age: Probably zone 13.

USGS colln. D2543 CO. Phi Kappa Formation, north of peak 10227. Altitude 9,400 ft. UTM grid, zone 11: E. 719,105 m, N. 4,859,280 m. Rock Roll Canyon quadrangle, Idaho.

Possibly *Glossograptus*
Age: In span of zones 9-12.

USGS colln. D2544 CO. Phi Kappa Formation, in tributary valley of Fall Creek north of peak 10227. Altitude 9,240 ft. UTM grid, zone 11: E. 719,185 m, N. 4,859,400 m. Rock Roll Canyon quadrangle, Idaho.

A small dichograptid, most likely *Dichograptus*
Holmograptus cf. *H. spinosus* (Ruedemann)
Cryptograptus schaferi (Lapworth)
Age: Zone 9.

USGS colln. D2545 CO. Phi Kappa Formation, west of Little Fall Creek. Altitude 9,360 ft. UTM grid, zone 11: E. 719,020 m, N. 4,859,765 m. Rock Roll Canyon quadrangle, Idaho.

Pterograptus? sp.
Phyllograptus anna J. Hall
Phyllograptus ilicifolius J. Hall
Tetragraptus cf. *T. serra* (Brogniart)
Didymograptus sp. (pendent form)
Didymograptus sp. (extensiform type)
Isograptus victoriae var.?
Isograptus caduceus?
Age: Zones 7-8—could well be zone 7.

USGS colln. D2546 CO. Phi Kappa Formation, west of Little Fall Creek. altitude 9,540 ft. UTM grid, zone 11: E. 718,950 m, N. 4,859,940 m. Rock Roll Canyon quadrangle, Idaho.

Dicranograptus sp.
Cryptograptus tricornis Carruthers
Glossograptus? sp.
Climacograptus cf. *C. typicalis* J. Hall
Pseudoclimacograptus sp.
Orthograptus? sp.
Diplograptus? sp.
Hallograptus? sp.
Age: Probably zones 12-13.

USGS colln. D2547 CO. Phi Kappa Formation. Altitude 9,800 ft. UTM grid, zone 11: E. 718,820 m, N. 4,859,655 m. Rock Roll Canyon quadrangle, Idaho.

Dicellograptus sp.
Uniserial stipes, possibly Leptograptid
Climacograptus spiniferus Ruedemann
Orthograptus of the *O. quadrimucronatus* type
Age: Probably zone 13.

USGS colln. D2548 CO. Phi Kappa Formation. Altitude 9,800 ft. UTM grid, zone 11: E. 718,820 m, N. 4,859,655 m. Rock Roll Canyon quadrangle, Idaho.

Corynoides calicularis Nicholson
Leptograptid
Orthograptus cf. *truncatus intermedius* Elles and Wood
Age: Probably zone 13.

USGS colln. D2549 CO. Phi Kappa Formation, east of peak 10244. Altitude 9,700 ft. UTM grid, zone 11: E. 718,660 m, N. 4,859,790 m. Rock Roll Canyon quadrangle, Idaho.

Graptolites badly sheared. One small specimen, probably *Climacograptus* or *Diplograptus*.
Age: Zones 9-14.

USGS colln. D2550 CO. Phi Kappa Formation, east of peak 10214. Altitude 9,650 ft. UTM grid, zone 11: E. 718,790 m, N. 4,860,500 m. Rock Roll Canyon quadrangle, Idaho.

Fragments of uniserial dichograptid stipes
Phyllograptus ilicifolius? J. Hall
Tetragraptus serra (Brogniart)
Didymograptus sp. (pendent)
Isograptus sp. (of *I. victoriae* group)
Cryptograptus schaferi? Carruthers
Climacograptus? sp.
Age: Probably zone 9.

USGS colln. D2551 CO. Phi Kappa Formation, west-northwest of Devils Bedstead, at head of Right Fork of Kane Creek. Altitude 9,390 ft. UTM grid, zone 11: E. 725,800 m, N. 4,852,655 m. Phi Kappa Mountain 7½-minute quadrangle, Idaho.

Pterograptus? sp. or *Pseudobryograptus*? sp.
Tetragraptus? cf. *T. serra* (Brogniart)
Tetragraptus quadribrachiatus (Hall)
Phyllograptus anna J. Hall
Phyllograptus ilicifolius J. Hall
Phyllograptus typus J. Hall
Didymograptus cf. *D. paraindentus* Berry
Isograptus victoriae lunatus Harris
Age: Zone 7.

USGS colln. D2552 CO. Phi Kappa Formation, 2 km north of Trail Creek summit. UTM grid, zone 11: E. 720,345 m, N. 4,857,930 m. Rock Roll Canyon quadrangle, Idaho.

Dicellograptus? sp.
Dicranograptus nicholsoni geniculatus Ruedemann and Decker
Dicranograptus ramosus? (J. Hall)
Climacograptus sp.
Orthograptus sp. of the *O. quadrimucronatus* group?
Age: Probably zone 13.

USGS colln. D2553 CO. Phi Kappa formation, northwest of Phi Kappa Mountain. Altitude 9,660 ft. UTM grid, zone 11: E. 724,440 m, N. 4,855,170 m. Phi Kappa Mountain quadrangle, Idaho.

Didymograptus sp. (extensiform type)
Dicellograptus sextans (J. Hall)
Glossograptus sp.
Nemagraptus sp.
Pseudoclimacograptus cf. *P. scharenbergi* (Lapworth)
Glyptograptus sp.
Diplograptus? sp.
Age: Probably zone 11.

USGS colln. D2554 CO. Phi Kappa Formation, west-facing slope above Trail Creek road, 1 km south of Summit. Altitude 8,260 ft. UTM grid, zone 11: E. 720,840 m, N. 4,855,170 m. Rock Roll Canyon quadrangle, Idaho.

Merely graphitic ghosts; perhaps *Cryptograptus* sp. and *Glyptograptus* cf. *G. intersitus* Harris and Thomas
Age: Somewhere between zones 8-15, possibly in zones 8-9.

USGS colln. D2555 CO. Phi Kappa Formation, east of D2554 but west of divide. Altitude 8,800 ft. UTM grdi, zone 11: E. 721,300 m, N. 4,855,130 m. Phi Kappa Mountain quadrangle, Idaho.

Small *Climacograptus,* possibly *C. putillus* (J. Hall)
Age: Latter part of Ordovician.

USGS colln. D2556 CO. Phi Kappa Formation. Altitude 8,400 ft. UTM grid, zone 11: E. 720,050 m, N. 4,856,650 m. Rock Roll Canyon quadrangle, Idaho.

Undetermined climacograptid
Age: Latter part of Ordovician.

USGS colln. D2557 CO. Phi Kappa Formation. Altitude 8,435 ft. UTM grid, zone 11: E. 719,990, N. 4,856,625 m. Rock Roll Canyon quadrangle, Idaho.

Leptograptus? (cf. *L. flaccidus* J. Hall)
Glyptograptus? sp. or *Diplograptus*? cf. *D. multidens diminutus* Ruedemann
Age: Probably zone 13 or 14.

USGS colln. D2558 CO. Phi Kappa Formation. Altitude 8,580 ft. UTM grid, zone 11: E. 719,555 m, N. 4,856,390 m. Rock Roll Canyon quadrangle, Idaho.

This collection is mixed, partly Ordovician, partly Silurian.
Divided by field numbers:
70-101a
Cryptograptus tricornis (Carruthers)
Climacograptus bicornis (J. Hall)
Age: Zone 12, zone of *C. bicornis*
70-101d
Monograptus flemingii (Salter)
Cyrtograptus sp.
70-101e
Cyrtograptus rigidus Tullberg
Age: These two collections are Silurian Wenlockian (zone of *Cyrtograptus rigidus*).

USGS colln. D2559 CO. Phi Kappa Formation. Altitude 8,440 ft. UTM grid, zone 11: E. 721,880 m, N. 4,855,775 m. Phi Kappa Mountain quadrangle, Idaho.

Orthograptus? sp.
Age: Latter part of Ordovician.

USGS colln. D2560 CO. Phi Kappa Formation. Altitude 8,920 ft. UTM grid, zone 11: E. 722,245 m, N. 4,855,915 m. Phi Kappa Mountain quadrangle, Idaho.

Perhaps *Tetragraptus serra* (Brogniart)
Phyllograptus cf. *P. anna* J. Hall
Didymograptus sp. (extensiform)
Isograptus victoriae Harris subsp.?
Pseudisograptus manubriatus (T. S. Hall)
Age: Zone 7 or 8—could well be zone 7. May be same as D2545 CO.

USGS colln. D2561 CO. Phi Kappa Formation. Altitude 9,860 ft. UTM grid, zone 11: E. 722,215 m, N. 4,856,410 m. Phi Kappa Mountain quadrangle, Idaho.

Dicellograptus sextans J. Hall
Pseudoclimacograptus cf. *P. scharenbergi* (Lapworth)
Glyptograptus cf. *G. teretiusculus* (Hisinger)
Age: Probably zones 11-12.

USGS colln. D2562 CO. Phi Kappa Formation. Altitude 10,025 ft. UTM grid, zone 11: E. 725,395 m, N. 4,855,090 m. Phi Kappa Mountain quadrangle, Idaho.

Pseudoclimacograptus scharenbergi (Lapworth)
Glyptograptus? sp.
Amplexograptid?
Age: Zones 9-15.

USGS colln. D2563 CO. Phi Kappa Formation. Altitude 9,480 ft. UTM grid, zone 11: E. 724,525 m, N. 4,855,380 m. Phi Kappa Mountain quadrangle, Idaho.

Dicellograptus sp.
Dicranograptus sp. (possibly of *D. kirki* type?)
Cryptograptus tricornis (Carruthers)
Glyptograptus sp.
Orthograptus of the *O. calcaratus* (Lapworth) type
Age: Zones 12-13.

USGS colln. D2564 CO. Phi Kappa Formation. Altitude 9,135 ft. UTM grid, zone 11: E. 719,825 m, N. 4,860,440 m. Rock Roll Canyon quadrangle, Idaho.

Diplograptus sp.
Age: Middle-Late Ordovician.

USGS colln. D2565 CO. Phi Kappa Formation (may not be in place). Altitude 8,200 ft. UTM grid, zone 11: E. 720,540 m, N. 4,857,730 m. Rock Roll Canyon quadrangle, Idaho.

Dicranograptus? sp.
Climacograptus bicornis J. Hall
Orthograptus? sp.
Age: Probably zone 12.

USGS colln. D2566 CO. Phi Kappa Formation (may not be in place). Altitude 8,085 ft. UTM grid, zone 11: E. 720,110 m, N. 4,857,475 m. Rock Roll Canyon quadrangle, Idaho.

Dicranograptus? sp.
Glyptograptus sp.
Age: Latter part of Ordovician.

USGS colln. D2568 CO. Phi Kappa Formation. Altitude 8,360 ft. UTM grid, zone 11: E. 719,910 m, N. 4,856,215 m. Rock Roll Canyon quadrangle, Idaho.

Climacograptus? cf. *C. supernus* Elles and Wood
Climacograptus? sp. possibly of *C. caudatus* Lapworth type
Age: Possibly zones 12–14.

USGS colln. D2590 CO. Same as D2516 CO. Phi Kappa Formation. Altitude 8,200 ft. UTM grid, zone 11: E. 720,110 m, N. 4,856,750 m. Rock Roll Canyon quadrangle, Idaho.

Dichograptus sp.
Tetragraptus sp.? *T. serra* (Brogniart)
Phyllograptus sp. (?*P. ilicifolius* J. Hall and ?*P. typus* J. Hall)
Didymograptus sp. (extensiform type)
Age: In span of zones 6–8.

USGS colln. D2591 CO. Phi Kappa Formation. Altitude 8,435 ft. UTM grid, zone 11: E. 719,995 m, N. 4,856,660 m. Rock Roll Canyon quadrangle, Idaho.

Dicellograptus sp.
Climacograptus spiniferus Ruedemann
Orthograptus truncatus (Lapworth)
Orthograptus quadrimucronatus (J. Hall)
Diplograptus sp. (probably new, aff. *D. multidens compactus* Elles and Wood)
Age: Zone 13.

USGS colln. D2592. Phi Kappa Formation. Altitude 8,445 ft. UTM grid, zone 11: E. 719,975 m, N. 4,856,650 m. Rock Roll Canyon quadrangle, Idaho.

Leptograptus?
Climacograptus sp.
Glyptograptus? sp.
Orthograptus cf. *O. quadrimucronatus* (J. Hall)
Orthograptus sp. (possibly *O. calcaratus* type)
Orthograptus sp. (of the *O. quadrimucronatus* type)
Age: In span of zones 13–14.

USGS colln. D2593 CO. Phi Kappa Formation. Altitude 8,460 ft. UTM grid, zone 11: E. 719,940 m, N. 4,856,635 m. Rock Roll Canyon quadrangle, Idaho.

Climacograptus sp.
Glyptograptus sp. (cf. *Glyptograptus* sp. in Ross and Berry, 1963, pl. 11, figs. 11, 12)
Orthograptus sp.
Age: Late Ordovician.

USGS colln. D2594 CO. Phi Kappa Formation. Altitude 8,470 ft. UTM grid, zonel 11: E. 719,935 m, N. 4,856,630 m. Rock Roll Canyon quadrangle, Idaho.

Dicellograptus ornatus minor Toghill
Glyptograptus? sp.
Orthograptus sp. (cf. *O. truncatus* (Lapworth) type)
Age: Zone 15.

USGS colln. D2595 CO. Phi Kappa Formation. Altitude 8,480 ft. UTM grid, zone 11: E. 719,820 m, N. 4,856,620 m. Rock Roll Canyon quadrangle, Idaho.

Dicellograptus ornatus minor Toghill
Climacograptus hvalross Ross and Berry
Climacograptus supernus Elles and Wood
Orthograptus calcaratus grandis (Ruedemann)
Age: Zone 15.

The altitude of the highest topographic point of the Trail Creek Summit section is 8,832 ft. On south side of 8,755 ft. a thick quartzite is exposed. Two collections were made above this quartzite.

USGS colln. D2596 CO. Phi Kappa Formation, 4 ft. above quartzite. UTM grid, zone 11: E. 719,800 m, N. 4,856,380 m. Rock Roll Canyon quadrangle, Idaho.

Phyllograptus angustifolius J. Hall
Didymograptus protobifidus Elles
Didymograptus sp.
Age: Zone 6.

USGS colln. D2597 CO. Phi Kappa Formation, 7 ft. above quartzite. UTM grid, zone 11: E. 719,495 m, N. 4,856,400 m. Rock Roll Canyon quadrangle, Idaho.

Didymograptus cf. *D. nicholsoni planus* Elles and Wood
Didymograptus sp. (cf. *D. similis* J. Hall)
Isograptus victoriae lunatus Harris
Isograptus victoriae victoriae Harris
Amplexograptus? sp.
Age: Zone 7.

USGS colln. D2604 CO. Formation uncertain. UTM grid, zone 11: E. 722,545 m, N. 4,856,360 m. Phi Kappa Mountain quadrangle, Idaho.

Problematical graptolites. This collection virtually lacks any thecate stipes. The dichotomously branched fragments suggest *Dendrograptus*, which has a range from Cambrian to Carboniferous.

USGS colln. D2605 CO. Phi Kappa Formation, crest of ridge between upper Summit and Phi Kappa Creeks. UTM grid, zone 11: E. 722,210 m, N. 4,856,410 m. Phi Kappa Mountain quadrangle, Idaho.

Dicellograptus sextans exilis Elles and Wood
Cryptograptus tricornis (Carruthers)
Climacograptus sp. (*bicornis* or *spiniferus*)
Glyptograptus sp.
Orthograptus sp.
Age: Zones 11–12.

USGS colln. D2606 CO. Phi Kappa Formation, on divide between Miller Canyon and Little Fall Creek. UTM grid, zone 11: E. 719,180 m, N. 4,861,835 m. Meridian Peak quadrangle, Idaho.

Dicellograptus sp.
Dicranograptus contortus Ruedemann
Dicranograptus sp.
Cryptograptus tricornis (Carruthers)
Climacograptus bicornis J. Hall
Age: Zone 12.

USGS colln. D2607 CO. Phi Kappa Formation, on divide between Miller Canyon and Little Fall Creek. Lies stratigraphically above D2606 CO in thrust sheet. UTM grid, zone 11: E. 718,925 m, N. 4,861,830 m. Meridian Peak quadrangle, Idaho.

Climacograptus sp.
Orthograptus quadrimucronatus (J. Hall)
A small spinose rhabdosome which is either a proximal end of *Orthograptus* or an immature *Glossograptus*
Age: Zone 14 or possibly zone 13.

USGS colln. D2608 CO. Phi Kappa Formation, on ridge between Miller Canyon and Little Fall Creek, in thrust sheet resting above collections D2606 CO and D2607 CO. UTM grid, zone 11: E. 717,885 m, N. 4,862,460 m. Meridian Peak quadrangle, Idaho.

Dicellograptus divaricatus (J. Hall)
Dicellograptus intortus Lapworth
Dicranograptus cf. *D. ramosus longicaulis* Elles and Wood
Cryptograptus sp.
Glossograptus sp.
Orthograptus cf. *O. quadrimucronatus* (J. Hall)
Diplograptus sp.
Age: Probably zone 12, but some elements should be younger and some might be older. Possibly a mixed collection.

USGS colln. D2682 CO. Phi Kappa Formation, north of Park Creek, approximately 0.8 km northwest of junction with Summit Creek. Approximate altitude 8,320 ft. UTM grid, zone 11: E. 719,980 m, N. 4,857,780 m. Rock Roll Canyon quadrangle, Idaho.

Biserial scandent graptolites; probably *Orthograptus*, possibly *Glyptograptus*
Age: Zone not determined—could be Middle Ordovician.

USGS colln. D2683 CO. Phi Kappa Formation, approximately 1.6 km northwest of junction of Park and Sumit Creeks. Approximate altitude 8,480 ft. UTM grid, zone 11: E. 719,740 m, N. 4,857,710 m. Rock Roll Canyon quadrangle, Idaho.

Relict small scandent biserial climacograptid.
Age: No older than latest Llanvirnian.

USGS colln. D2684 CO. Phi Kappa Formation, in east side of tributary gully north of Park Creek. Approximate altitude 8,760 ft. UTM grid, zone 11: E. 719,420 m, N. 4,857,970 m. Rock Roll Canyon quadrangle, Idaho.

One very small graptolite might be a specimen of *Cryptograptus*. Other specimens are so badly sheared that recognition is virtually impossible.
Age: Could be Late Llanvirnian to mid-Caradocian but this age is very tenuous.

USGS colln. D2685 CO. Phi Kappa Formation, on sharp ridge north of Park Creek. Approximate altitude 9,000 ft. UTM grid, zone 11: E. 719,200 m, N. 4,857,930 m. Rock Roll Canyon quadrangle, Idaho.

Dicranograptus (very uncertain)
Climacograptus sp.
Age: Probably zone 12–14.

USGS colln. D2686 CO. Phi Kappa Formation, on ridge north of Park Creek. Approximate altitude 9,100 ft. UTM grid, zone 11: E. 719,195 m, N. 4,857,860 m. Rock Roll Canyon quadrangle, Idaho.

Climacograptus bicornis J. Hall
Orthograptus calcaratus (Lapworth)
Age: Probably zone 12.

USGS colln. D2687 CO. Phi Kappa Formation, on ridge north of Park Creek. Approximate altitude 8,800 ft. UTM grid, zone 11: E. 719,255 m, N. 4,857,670 m. Rock Roll Canyon quadrangle, Idaho.

Dicranograptus cf. *D. nicholsoni* Hopkinson
Glossograptus sp.
Orthograptus? sp.
Age: Probably zones 11–12.

USGS colln. D2688 CO. Phi Kappa Formation, west of tributary gully north of Park Creek. Approximate altitude 8,390 ft. UTM grid, zone 11: E. 719,640 m, N. 4,857,500 m. Rock Roll Canyon quadrangle, Idaho.

Climacograptus cf. *C. eximius* Ruedemann
Climacograptus sp. (small)
Other fragments
Age: Probably zones 11–12.

USGS colln. D2689 CO. Phi Kappa Formation, east of junction of Trail Creek and West Fork. Approximate altitude 8,440 ft. UTM grid, zone 11: E. 718,060 m, N. 4,858,105 m. Rock Roll Canyon quadrangle, Idaho.

Dicellograptus cf. *D. divaricatus salopiensis* Elles and Wood
Climacograptus bicornis (J. Hall)
Climacograptus sp.
Age: Probably zone 12.

USGS colln. D2690 CO. Phi Kappa Formation, east of junction of Trail Creek and West Fork. Altitude approximately 8,440 ft. UTM grid, zone 11: E. 718,100 m, N. 4,858,170 m. Rock Roll Canyon quadrangle, Idaho.

Climacograptus sp. (width about 1.5 mm; thecae 15-16 per 10 mm).
Others indeterminate.
Age: Uncertain—post-Early Ordovician.

USGS colln. D2693a-l CO. Phi Kappa Formation, section on Little Fall Creek. UTM grid, zone 11: E. 719,185 m, N. 4,859,420 m. Rock Roll Canyon quadrangle, Idaho. Lowest collection at altitude of 9,207 ft. on southeast side of tributary creek.

D2693a CO. Lowest collection very close to D2502 CO. Altitude 9,207 ft.

Phyllograptus sp.
Phyllograptus cf. *P. nobilis*
Didymograptus sp. (extensiform type)
Isograptus caduceus australis Cooper
Cardiograptus morsus Harris and Keble
Oncograptus upsilon T. S. Hall
Glossograptus hincksii (Hopkinson)
Glyptograptus austrodentatus austrodentatus Harris and Keble
Glyptograptus austrodentatus americanus Bulman
Age: Zone 8.

D2693b CO. Twenty-two stratigraphic feet above D2693a CO. Southeast side of creek. Altitude 9,219 ft.

Isograptus victoriae lunatus Harris
Age: Probably zone 8—in zone 7-9 span.

D2693c CO. Eleven stratigraphic feet above D2693b CO. Southeast side of creek. Altitude 9,226 ft.

Dichograptus sp.
Tetragraptus amii Elles and Wood
Isograptus caduceus imitatus Harris
Isograptus caduceus australis Cooper
Isograptus forcipiformis (Ruedemann)
Pseudisograptus dumosus Harris
Glossograptus acanthus Elles and Wood
Cryptograptus schaferi Lapworth
Glyptograptus austrodentatus austrodentatus Harris and Keble
Glyptograptus austrodentatus americanus Bulman
Age: Probably zone 8—in zone 7-9 span.

D2693d CO. On northwest side of tributary creek, 1 ft stratigraphically above D2693b CO. Altitude 9,219 ft.

Tetragraptus sp.
Didymograptus cf. *D. hemicyclus* Harris
Isograptus caduceus imitatus Harris
Isograptus caduceus australis Cooper
Glyptograptus austrodentatus austrodentatus Harris and Keble
Glyptograptus austrodentatus americanus Bulman
Age: Probably zone 8—certainly in zone 8-9 span.

D2693e CO. On northwest side of tributary creek, 4 ft stratigraphically below D2693d CO. Altitude 9,217 ft.

Isograptus forcipiformis (Ruedemann)?
Age: In zone 8-9 span.

D2693f CO. On northwest side of tributary creek, 11 ft stratigraphically below D2693e CO. Altitude 9,212 ft.

Glossograptus acanthus Elles and Wood
Glyptograptus austrodentatus austrodentatus Harris and Keble
Age: In zone 8-9 span.

D2693g CO. On southeast side of tributary creek, about at top of small falls and about 50 ft stratigraphically above D2693b. Altitude 9,280 ft.

Dichograptus sp.
Pseudobryograptus sp. (cf. *P. incertus* (Harris and Thomas))
Tetragraptus cf. *T. amii* Elles and Wood
Didymograptus sp.
Isograptus caduceus imitatus Harris
Isograptus forcipiformis Ruedemann?
Pseudisograptus dumosus Harris
Glossograptus hincksii (Hopkinson)
Glyptograptus austrodentatus austrodentatus Harris and Keble
Glyptograptus austrodentatus americanus Bulman
Age: Zone 9.

D2693h CO. Southeast side of tributary creek, about 20-25 ft stratigraphically above D2693g CO. Altitude 9,315 ft.

Didymograptus sp. cf. *D. cuspidatus* Ruedemann
Isograptus forcipiformis (Ruedemann)
Cardiograptus morsus Harris and Keble
Holmograptus spinosus (Ruedemann)
Glossograptus hincksii (Hopkinson)
Cryptograptus schaferi Lapworth
Diplograptus decoratus multus Ross and Berry
Age: Zone 9.

D2693i CO. Southeast side of tributary creek, above D2693h CO. Approximate altitude 9,400 ft.

Tetragraptus aff. *T. quadribrachiatus* (J. Hall)
Phyllograptus? sp.
Didymograptus sp. cf. *D. cuspidatus* Ruedemann
Paraglossograptus? sp.
Climacograptus cf. *C. riddellensis* Harris
Age: Zone 9.

D2693j CO. Southeast side of tributary creek and 10-15 ft stratigraphically above D2693i CO. Altitude 9,412 ft.

Diplograptus decoratus cf. var. *multus* Ross and Berry
Age: In span of zones 9-10.

D2693k CO. Southeast side of creek and 35-40 ft stratigraphically above D2693j CO. Altitude 9,460 ft.

Cryptograptus schaferi Lapworth
Glyptograptus cf. *G. euglyphus* (Lapworth)
Diplograptus cf. *D. decoratus multus* Ross and Berry
Age: In span of zones 9-10.

D2693l CO. Northwest side of tributary creek on slope northwest of creek in area of small outcrop about 10–15 ft above D2693k CO. Altitude 9,480 ft.

Climacograptus cf. *C. riddellensis* Harris
Glyptograptus cf. *G. euglyphus* (Lapworth)
Diplograptus decoratus multus Ross and Berry
Lasiograptus sp.
Age: Zone 10.

USGS colln. D2715 CO. Phi Kappa Formation, 6 ft above road level and about 12 ft below lowest Silurian graptolite collection at type section of the Trail Creek Formation (Westgate and C. P. Ross, 1930). West side of Trail Creek. Approximate altitude 8,040 ft. UTM grid, zone 11: E. 717,010 m, N. 4,859,650 m. Rock Roll Canyon quadrangle, Idaho.

Two associations appear to be present in this collection.

One of the two includes:

Climacograptus sp. (including possible *C. miserabilis* and *C. hastatus*)
Dicellograptus ornatus minor Toghill
Orthograptus truncatus abbreviatus Elles and Wood
Orthograptus truncatus socialis (Lapworth)
Age: Zone 15.

The other association includes:

Climacograptus sp. (*C. styloideus* Elles and Wood?)
Dicellograptus elegans (Carruthers)?
Dicranograptus sp. (cf. *D. nicholsoni*)
Age: Zone 14.

SILURIAN GRAPTOLITE COLLECTIONS

Collection D2558 CO was made early in the mapping program before the structural complexity was realized. It is a mixed collection of Ordovician and Silurian elements and is in numerical sequence in the Ordovician list. Another collection, D2539 CO, originally logged as Ordovician has proved to be Middle Silurian in age and is listed here. All other Silurian collections are from the type section of the Trail Creek Formation. Silurian zones shown below are those of Elles and Wood (1901–14).

USGS colln. D2539 CO. Formation uncertain, 130 m southeast of mouth of Cold Canyon on west side of Trail Creek. UTM grid, zone 11: E. 718,615 m, N. 4,856,490 m. Rock Roll Canyon quadrangle, Idaho.

Monograptus of the *M. priodon* (Brown) type
Monoclimacid
Age: Wenlockian.

The following collections all came from essentially the same locality, the type section of the Trail Creek Formation (Westgate and C. P. Ross, 1930), but in beds below the banded siliceous metasiltstone beds to which the formation is herein restricted.

Principal reference section of Trail Creek Formation, west side of Trail Creek. Approximate altitude 8,020 ft. UTM grid, zone 11: E. 717,010 m, N. 4,859,650 m. Rock Roll Canyon quadrangle, Idaho.

USGS colln. D337SD. Phi Kappa Formation of this report, 12 m above road level.

Monograptus convolutus (Hisinger)
Monograptus limatulus Tornquist?
Biserial form?
Age: Llandoverian—zone 20 (*Monograptus convolutus*).

USGS colln. D338SD. Phi Kappa Formation of this report, 1.5 m above D337SD.

Cyrtograptus rigidus Tullberg?
Monograptus flemingii (Salter)
Monograptus retroflexus Tullberg?
Age: Probably about mid-Wenlockian—zone 30 of Elles and Wood (*Cyrtograptus rigidus*).

USGS colln. D346SD. Phi Kappa Formation of this report, a few inches above D347SD.

Shredded specimens of cyrtograptids and monograptids.
Age: Silurian.

USGS colln. D347SD. Phi Kappa Formation of this report, 13.5 m above road level.

Cyrtograptus cf. *C. perneri* Boucek
Diversograptid?
Monoclimacis cf. *M. flumendosae* (Gortani)
Monograptus flemingii (Salter)
Age: Middle Wenlockian.

USGS colln. D348SD. Phi Kappa Formation of this report, 10.5 m above road level.

Monograptus priodon (Brown)
Monograptus sp. (of the *M. spiralis* (Geinitz) group)
Retiolites geinitzianus (Barrande)
Age: Late Llandoverian.

USGS colln. D349SD. Phi Kappa Formation of this report, 4.5 m above road level.

Monograptus sp. (cf. *M. revolutus* Kirk)
Climacograptids
Age: Middle Llandoverian.

USGS colln. D354SD. Phi Kappa Formation of this report, 6.4 m above road level.

Glyptograptus sp.
Monograptus convolutus (Hisinger)
Age: Llandoverian—probably zone 20 (*M. convolutus*).

USGS colln. D355SD. Phi Kappa Formation of this report, 5.4 m above road level.

Dimorphograptus sp.
Glyptograptus sp.
Monograptus sp. (fragments similar to *M. revolutus* and *M. atavus*)
Age: Early part of Llandoverian—about zones 17–18.

USGS colln. D356SD. Phi Kappa Formation of this report, 16 m above road level.

Monograptus sp. of the *M. priodon* group
Age: In span of late Llandoverian to Wenlockian.

USGS colln. D357SD. Phi Kappa Formation of this report, 19 m above road level.

Crytograptid?
Monoclimacis sp.
Monograptus cf. *M. priodon* (Bronn)
Age: In span of late Llandoverian to Wenlockian.

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PLATES 2–6

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PLATE 2

FIGURE 1. *Didymograptus protobifidus* Elles (p. 24). Two specimens showing characteristic form. × 5. USNM 24116. USGS colln. D2596 CO.

2. *Didymograptus bifidus* (J. Hall) (not described). Immature rhabdosome? or *D. protobifidus/D. bifidus* transient. × 10. USNM 241155, USGS colln. D2696 CO.

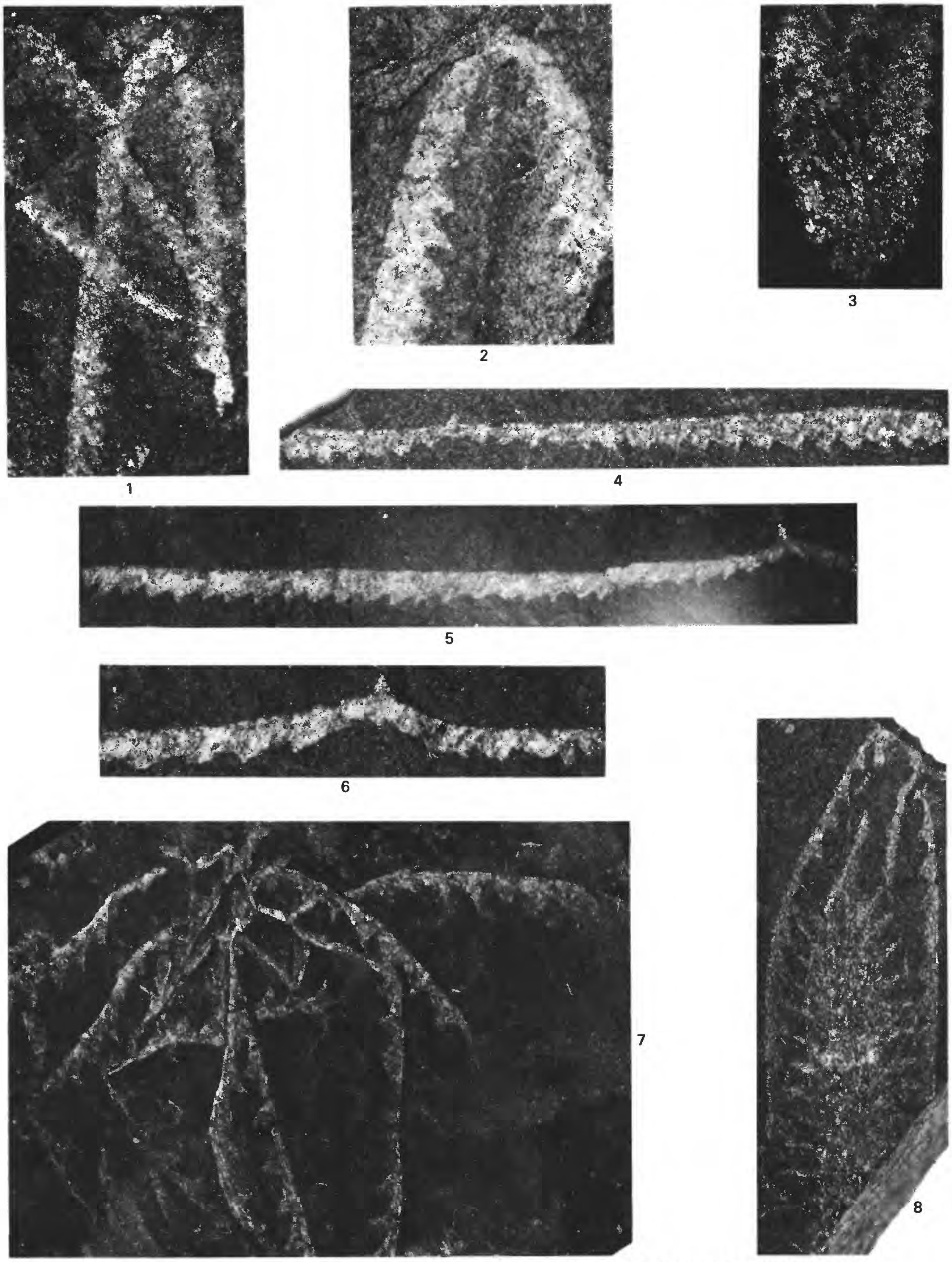
3. *Oncograptus upsilon* T. S. Hall (p. 31). Immature rhabdosome? × 5. USNM 241139, USGS colln. D2693a CO.

4, 5. *Didymograptus* sp. (p. 25).
× 5. USNM 241117, USGS colln. D2693h CO.
× 5. USNM 241118, USGS colln. D2597 CO.

6. *Didymograptus* cf. *D. nicholsoni planus* Elles and Wood (p. 24). Proximal region of immature rhabdosome. × 10. USNM 241115, USGS colln. D2597a CO.

7. *Psuedobryograptus incertus* (Harris and Thomas)? (p.22) Distorted specimen. × 5. USNM 241111, USGS colln. D2516a CO.

8. *Glossograptus hincksii* (Hopkinson) (p. 32). Rhabdosome overlies specimen of possible *Pseudobryograptus* sp.. × 5. USGS colln. D2693g CO. *Glossograptus hincksii* (Hopkinson), USNM 241142a. *Pseudobryograptus*? sp., USNM 241142b.



DIDYMOGRAPTUS, *ONCOGRAPTUS*, *PSEUDOBRYOGRAPTUS*, AND *GLOSSOGRAPTUS*

PLATE 3

FIGURE 1. *Didymograptus* cf. *D. hemicyclus* Harris (p. 23). × 10. USNM 241114, USGS colln. D2693d CO.

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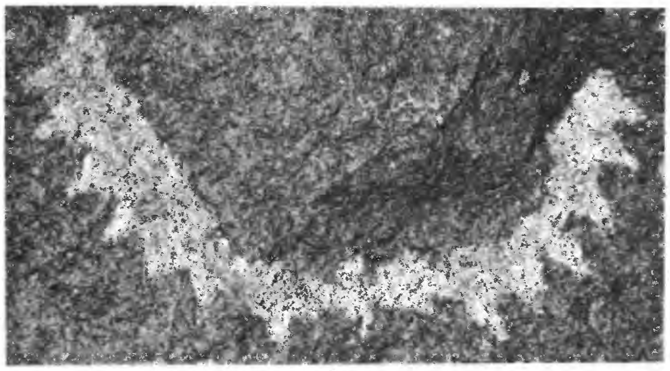
3. *Isograptus caduceus imitatus* Harris (p. 27). × 5. USNM 241124, USGS colln. D2693c CO.

4. *Psuedisograptus manubriatus* (T. S. Hall) (p.30) Two specimens showing manubrium shape and rhabdosome form. × 5. USNM 241136, USGS colln. D2560 CO.

5. *Pseudisograptus dumosus* (Harris) (p. 30). × 10. USNM 241134, USGS colln. D2516b CO.

6. *Dichograptus* sp. (p. 22). Specimen showing rhabdosome and thecal shape. × 5. USNM 241112, USGS colln. D2693c CO.



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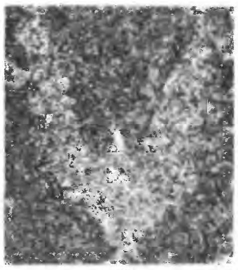

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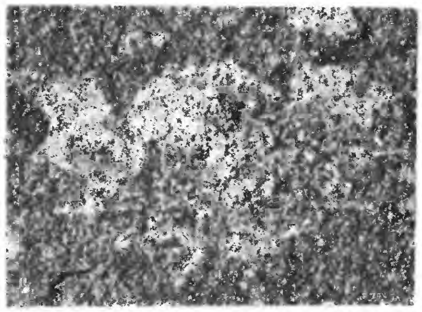

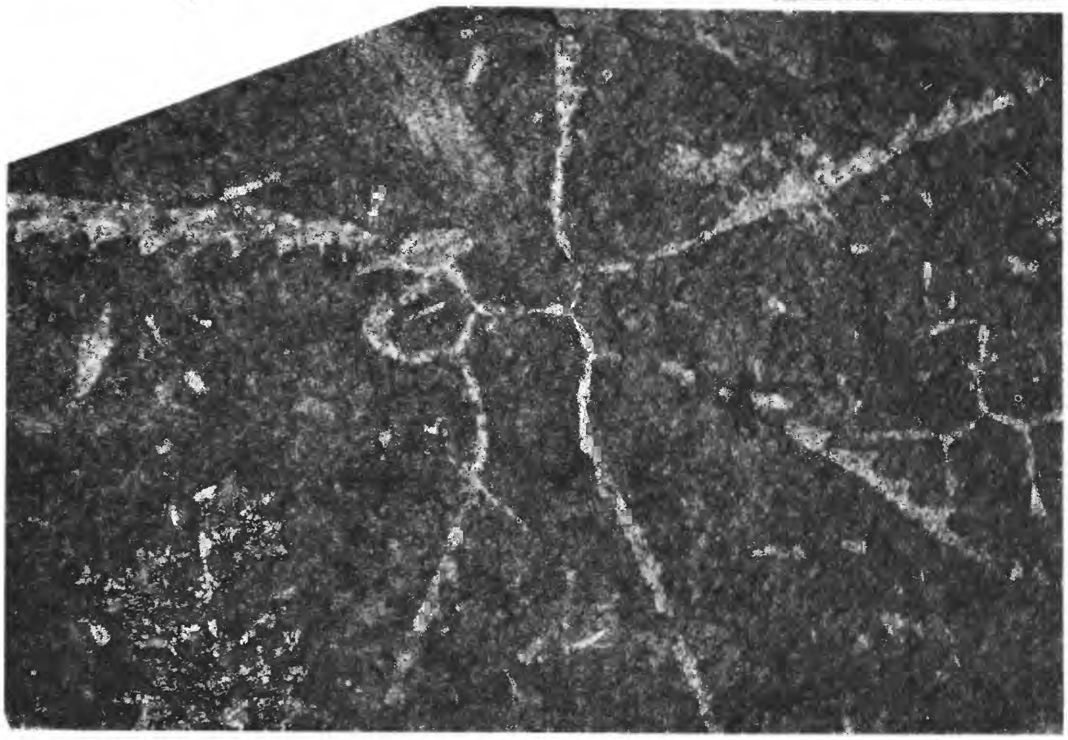

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DIDYMOGRAPTUS, *ISOGRAPTUS*, *PSEUDISOGRAPTUS*, AND *DICHOGRAPTUS*

PLATE 4

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3. × 5. USNM 241119, USGS colln. D2693a CO.

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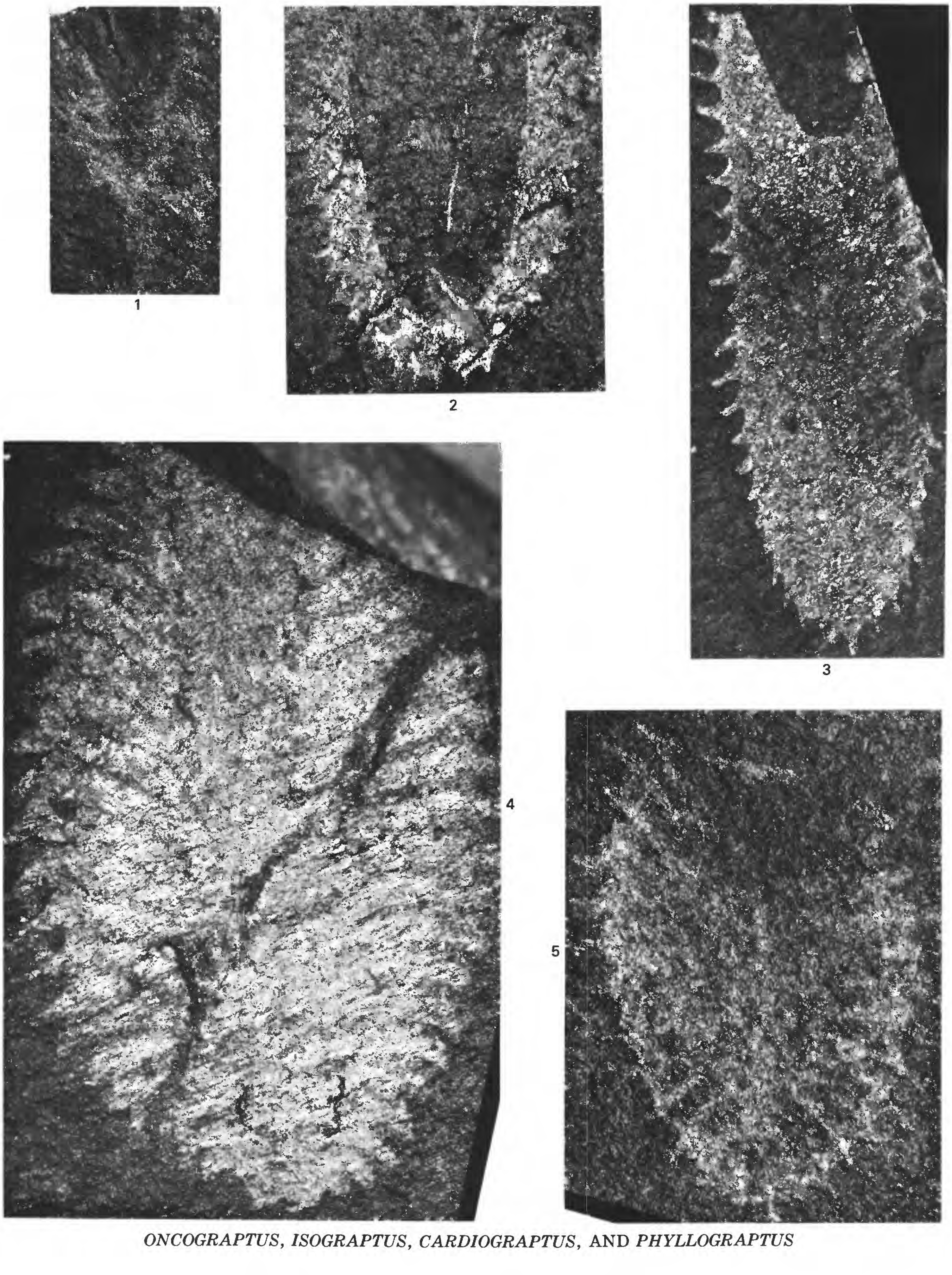
4. *Phyllograptus* sp. (p. 23). Showing rhabdosome form and thecal curvature. × 10. USNM 241113, USGS colln. D2693a CO.



ONCOGRAPTUS, *ISOGRAPTUS*, *CARDIOGRAPTUS*, AND *PHYLLOGRAPTUS*

PLATE 5

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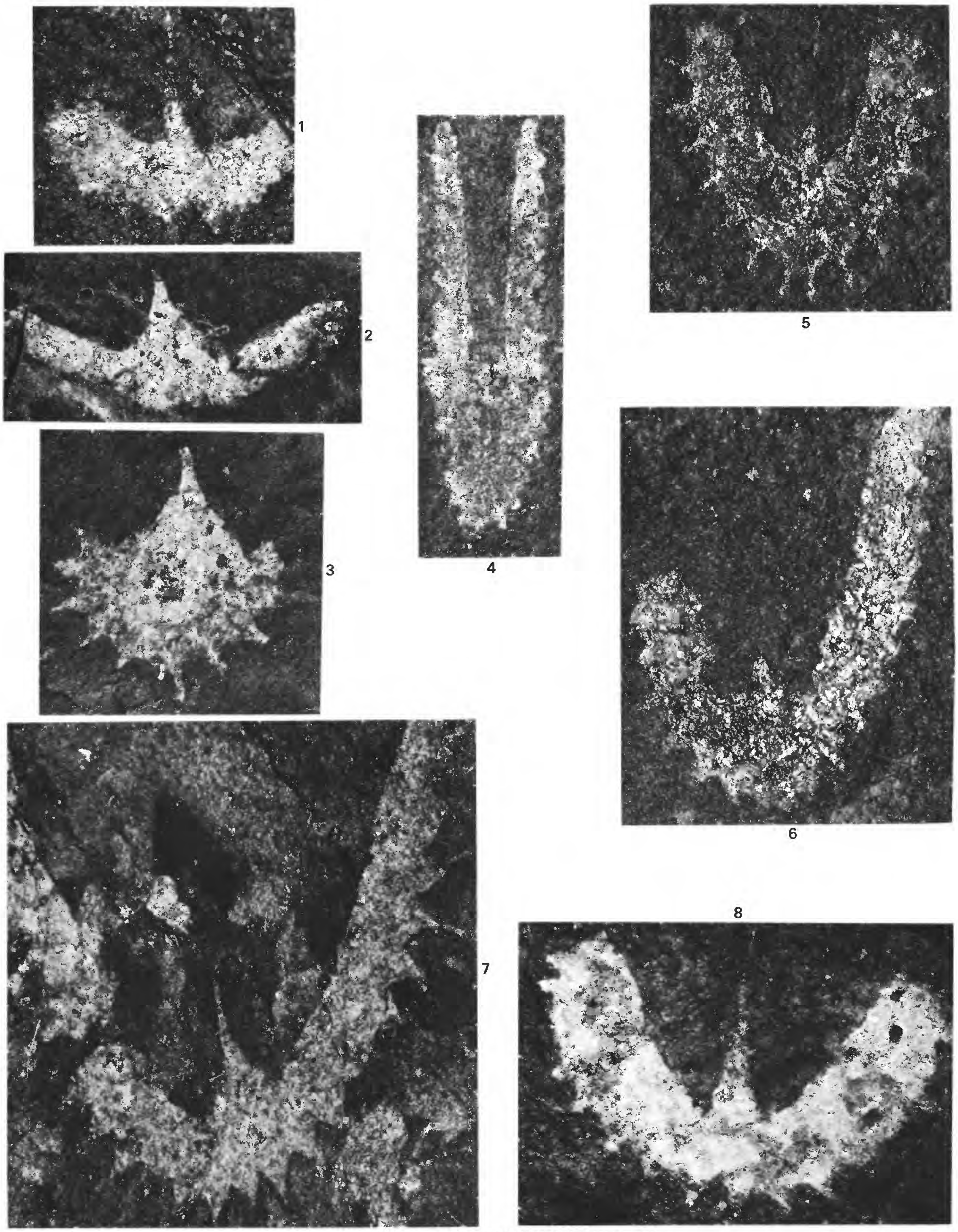
7. *Pseudisograptus manubriatus* (T. S. Hall) (p. 30). × 10. USNM 241137, USGS colln. D2516a CO.



ISOGRAPTUS AND *PSEUDISOGRAPTUS*

PLATE 6

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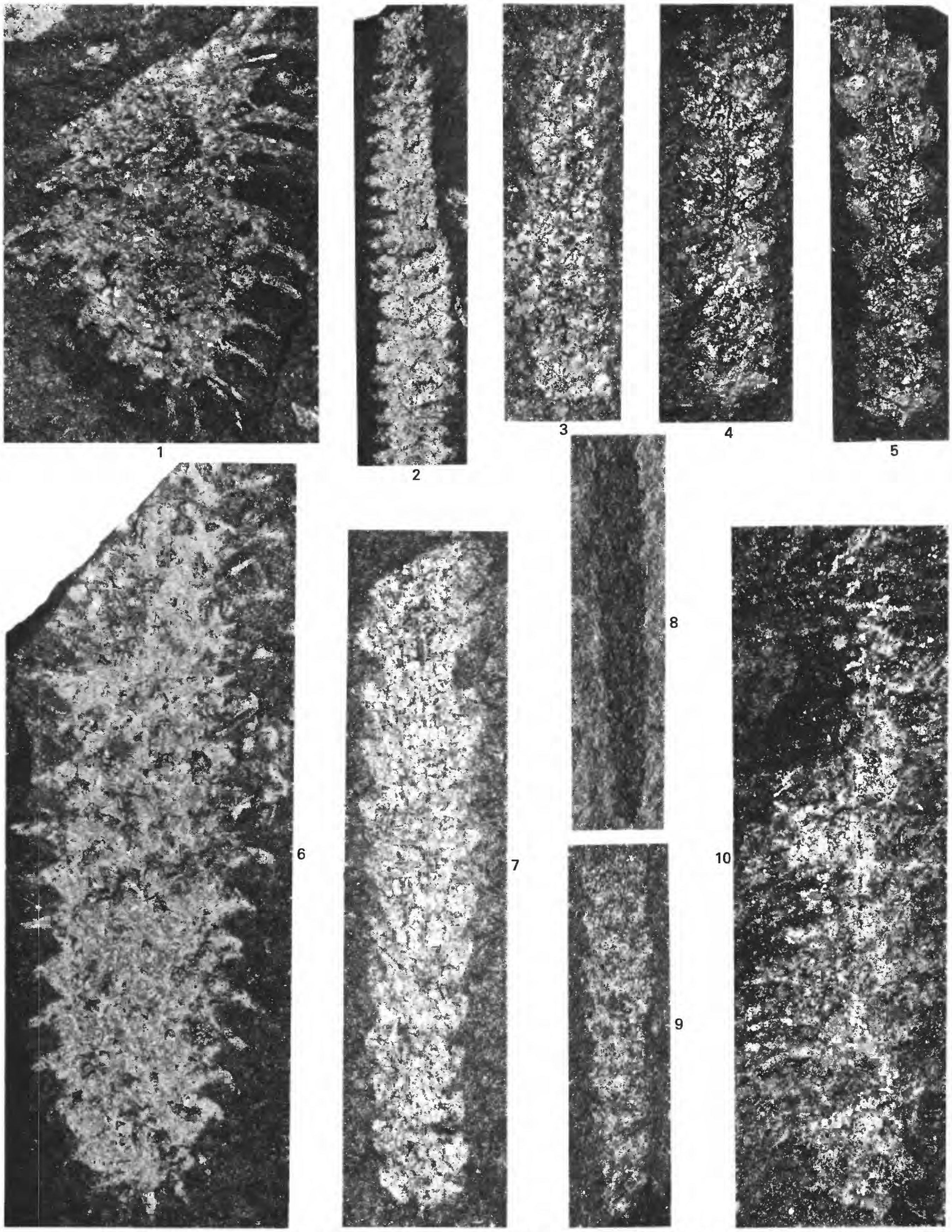

GLOSSOGRAPTUS, AMPLEXOGRAPTUS, GLYPTOGRAPTUS, AND *PARAGLOSSOGRAPTUS*