In regard to:

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the reader is advised that additional fossil data caused the author to modify the conclusions expressed in this paper. For the later information, please see

Schuster, J. Eric; Repetski, John E.; Carter, Claire; Dutro, J. Thomas, Jr., 1989, Nature of the Metaline Formation-Ledbetter Formation contact and age of the Metaline Formation in the Clugston Creek area, Stevens County, Washington--A reinterpretation: Washington Geologic Newsletter, v. 17, no. 4, p. 13-20.

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Geology of the Clugston Creek area, Stevens County, Washington

by

J. Eric Schuster

June, 1976

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INTRODUCTION

The Josephine Breccia (defined by Mills, 1976) is the host rock for many zinc-lead deposits in Stevens and Pend Oreille Counties. Because of the past and possible future economic importance of zinc and lead deposits in the Josephine Breccia, it is important to learn as much as possible about the origin of the Josephine and its mineral deposits and their relationship to the overlying Ordovician Ledbetter Slate and underlying Cambrian Metaline Limestone. The purpose of this report is to describe the Metaline Limestone-Ledbetter Slate contact and the Josephine Breccia in the Clugston Creek area, located about 12 airline miles north of Colville, in Stevens County. Because this report is concerned primarily with the Metaline-Ledbetter contact and its relationship to the Josephine Breccia, no description of rocks overlying the Ledbetter Slate or underlying the Metaline Limestone will be given.

I have benefited greatly from discussions and field trips with J. W. Mills of the Geology Department of Washington State University. Many of the concepts expressed here regarding the Metaline-Ledbetter contact, the Josephine Breccia, and zinc-lead mineralization in Stevens County grew out of these trips and conversations. Karl Frost served as my field assistant during the summers of 1972 and 1973, and Jon Sondergaard assisted during the 1975 field season.

CAMBRIAN SYSTEM

METALINE LIMESTONE

Description

In the Clugston Creek area the Metaline Limestone crops out in a belt extending from sections 25 and 26 northward to sections 1, 2, and 3, T. 37 N., R. 39 E. (figure 1). The most continuous outcrop across the formation is found on the east-west-oriented summit of Uncle Sam Mountain in the southern parts of sections 1, 2, and 3. Other outcrops occur on the summits and south-facing slopes of Baldy and Comstock and several other less prominent peaks and ridges. A mantle of glacial material conceals the Metaline Limestone over most of the areas of valley bottoms and north-facing slopes.

EXPLANATION FOR FIGURE 1
GEOLOGIC MAP OF THE CLUGSTON CREEK AREA
STEVENS COUNTY
WASHINGTON

Age	Symbol	Description
CRET.	Ks	SPIRIT PLUTON, GRANODIORITE
PERM.	Pu	PILLOW LAVA, ARGILLITE
ORDOVICIAN		LEDBETTER SLATE:
	Olu	UPPER; BLACK SLATE, CARBONATES IN UPPER PART.
	Olm	MIDDLE; SLATE AND ARGILLITE WITH QUARTZITE BEDS.
	Oll	LOWER; SLATE, ARGILLITE, AND SHALE WITH BLACK LIMESTONE AND BLACK DOLOMITE BEDS.
		— UNCONFORMITY —
CAMBRIAN		METALINE LIMESTONE:
	€mu	UPPER; GRAY, MOTTLED LIMESTONE, DOLOMITIZED IN PLACES, SOMETIMES WITH CHERTY NODULES.
	€mm	MIDDLE; GRAY DOLOMITE, SOMETIMES CRYSTALLINE, SOMETIMES WELL-BEDDED, SOMETIMES AN INTRAFORMATIONAL BRECCIA.
	€ml	LOWER; DARK GRAY THIN-BEDDED LIMESTONE WITH UNDULATORY BEDDING AND BROWN-WEATHERING SHALY PARTINGS.
	€m	MAITLEN PHYLLITE: PHYLLITE, QUARTZOSE PHYLLITE, INTERBEDDED PHYLLITE AND QUARTZITE AND WHITE TO GRAY LIMESTONE.
	€q	GYPSY QUARTZITE: WHITE TO GRAY QUARTZITE, SOMETIMES WITH PHYILLITE PARTINGS AND BEDS.

CONTACT, DASHED WHERE CONCEALED.

FAULT, DASHED WHERE CONCEALED.

OUTCROP AREAS

41 — STRIKE AND DIP OF BEDDING

25 — STRIKE AND DIP OF JOINTS

60 — STRIKE AND DIP OF FOLIATION

70 — STRIKE AND DIP OF SLATY CLEAVAGE

53 — TREND AND PLUNGE OF MINOR FOLD AXIS

ANTICLINE

SYNCLINE

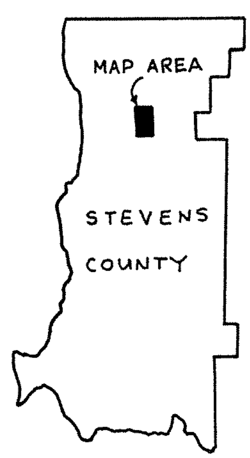
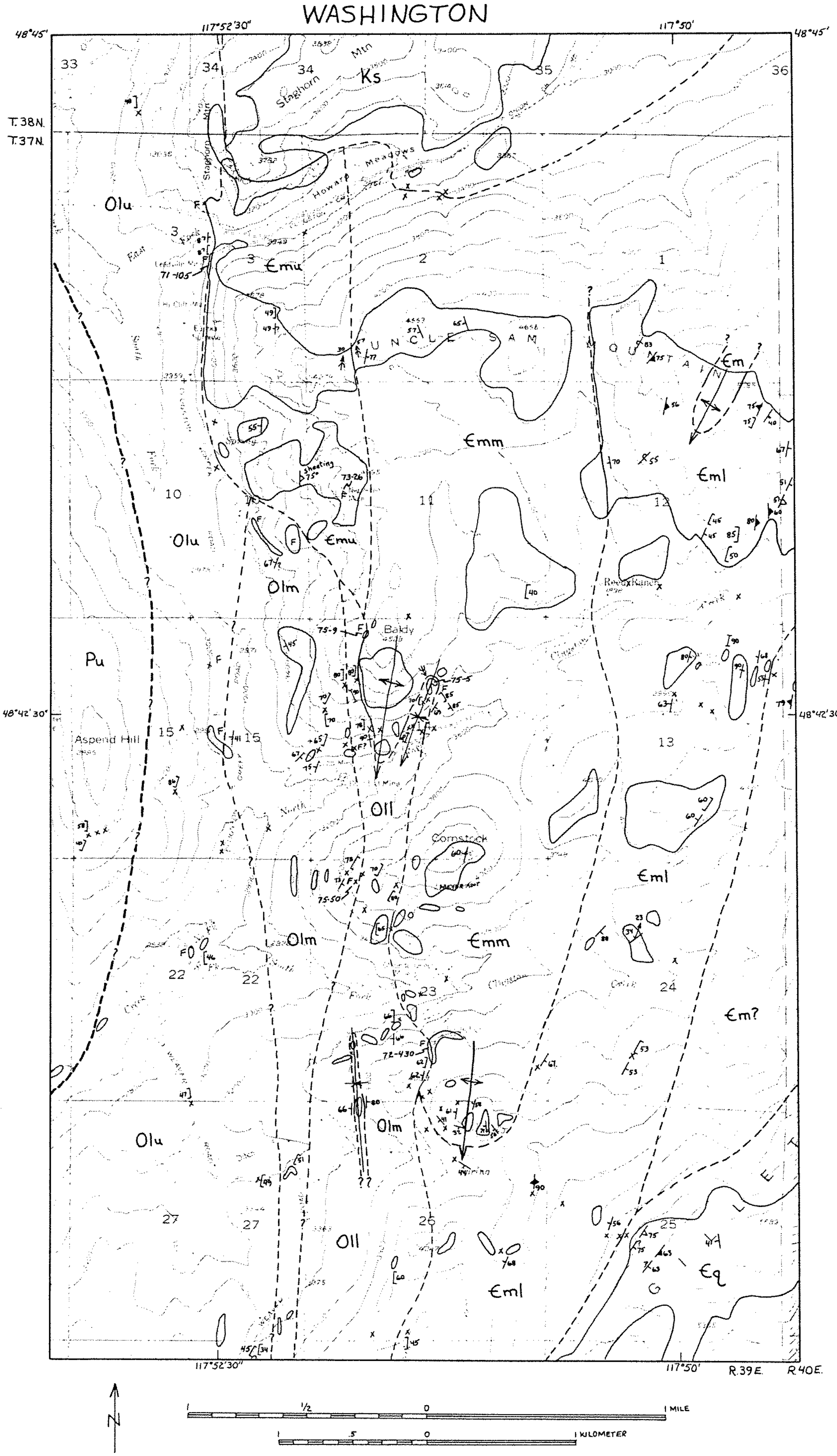


FIGURE 1

GEOLOGIC MAP OF THE CLUGSTON CREEK AREA STEVENS COUNTY WASHINGTON



Thickness and stratigraphic relations

In the Clugston Creek area the Metaline Limestone consists of three lithologic units; a lower unit of dark-gray bedded limestone and argillaceous limestone, a middle unit of dolomite, and an upper unit of light to dark gray, generally massive translucent limestone. These or similar units have been recognized by other geologists over much of Pend Oreille and northern Stevens Counties (Park and Cannon, 1943; Dings and Whitebread, 1965; Yates, 1964, 1971).

The upper two units dip westward at moderate to fairly steep angles, but stratification is discernible at relatively few places. The upper unit, where it crops out on the west end of Uncle Sam Mountain, has an apparent thickness of 2,600 feet. The upper limestone thins rapidly southward and the Ledbetter Slate rests directly on the middle dolomite on the west side of Baldy. To the north, the upper unit is cut off by the Spirit pluton, so its total outcrop length is only about 2 miles in the Clugston Creek area.

The middle dolomite unit of the Metaline Limestone on Uncle Sam Mountain is apparently 4,600 feet thick. This unit also thins to the south and extends only as far as the hills about one-quarter of a mile south-southeast of the Tenderfoot mine. A few outcrops in the north half of section 2 (see figure 1) show that the middle dolomite is cut off at the north by the Spirit pluton. Cox and Hollister (1955) reported a sharp eastward deflection of the contact between the middle and lower units of the Metaline Limestone on the north slope of Uncle Sam Mountain, and their map shows that the Chollet prospect in the northeast quarter of section 1 is underlain by middle Metaline dolomite. I have not shown this deflection on the map because there is no outcrop on the north slope of Uncle Sam Mountain in section 1. Cox and Hollister had the benefit of geophysical data, bulldozer trenches, and drilling data and are undoubtedly correct. They also show this contact as a fault for which I have found some evidence, even though I have not shown the contact as a fault in figure 1. This will be discussed below.

The lower limestone unit of the Metaline Limestone has as apparent thickness of 3,000 feet in the southern part of section 1. This unit does not appear to thin toward the south, at least within the area of Figure 1, but the lower unit has not been recognized further to the south, except in a few scattered outcrops, and thinning may well take place.

The lower contact of the Metaline Limestone is not exposed in the area of figure 1. On the east end of Uncle Sam Mountain (just east of the area of figure 1) the lower limestone unit appears to rest with an angular discordance on limestone that may be part of the Cambrian Maitlen Phyllite. To the south the Maitlen(?) thins, until in section 25 the lower Metaline Limestone apparently rests against the Cambrian Gypsy Quartzite. The lower contact of the Metaline Limestone may be a fault or an angular unconfirmity.

The upper contact of the Metaline Limestone is an angular unconformity. At the north end of the map area the Ledbetter Slate rests on upper Metaline Limestone. The upper unit thins rapidly southward, and from Baldy to the area of the Tenderfoot mine the Ledbetter Slate rests on the middle Metaline dolomite. In section 26 the Ledbetter probably rests on the lower limestone unit of the Metaline Limestone, but the contact is not exposed. The contact between the Ledbetter Slate and the Metaline Limestone can be demonstrated in several places to be a nearly undisturbed sedimentary contact. The nature of the contact is discussed more fully in the section on thickness and stratigraphic relations of the Ledbetter Slate.

Lithology and Internal Relations

The lower unit of the Metaline Limestone is a gray to dark-gray argillaceous limestone. Bedding is usually present and is defined by thin, brown-weathering, undulating shaly laminae. The laminae are not usually continuous for any distance but pinch and swell and join in places to leave "eyes" of less argillaceous limestone surrounded by shaly laminae. For at least as far south as the old marble quarry in the northwest quarter of section 13, the lower member has been affected by contact metamorphism of the Spirit pluton. Effects range from bleaching, some coarsening of grain size in the carbonates, and considerable development of micas in the shaly laminae, to a barely perceptible bleaching in the south half of section 13.

On Uncle Sam Mountain the upper part of the lower unit contains at least one bed, perhaps 100 feet thick, of almost pure limestone which has been bleached white and recrystallized by contact metamorphism. The lower unit grades into the underlying Maitlen Phyllite in the southeast quarter of section 1 and northeast quarter of section 12. The limestone becomes more phyllitic toward the contact, and the contact is placed approximately where noncalcareous phyllite predominated over carbonate-bearing rock.

The contact between the lower and middle units is nowhere exposed. The uppermost beds of the lower unit in the northwest quarter of section 12 are dark-gray limestone with brown-weathering laminae of argillaceous limestone. Bedding in the lower unit parallels the contact. In the southwest quarter of section 1 the uppermost exposed beds of the lower unit are dark-gray, fine-grained, massive limestone with irregular, contorted layers of white limestone. Somewhat farther from the contact, the rock is a dark-gray, fine-grained limestone with irregular laminae and thin beds of brown-weathering argillaceous limestone. West of the contact the middle unit is a medium- to light-gray, massive, crystalline dolomite that is often brecciated. Voids between breccia fragments are filled with coarse-grained dolomite. This suggests that the uppermost exposed beds of the lower unit are at different stratigraphic levels and that the contact between the middle and lower units is not a normal sedimentary contact. Taken together, these relationships suggest the presence of a fault between the middle and lower units of the Metaline Limestone.

On Uncle Sam Mountain, the middle dolomite is a fine- to fairly coarse-grained, massive, white to creamy-gray dolomite. In places there are lenses up to about 4 feet thick of black dolomite with white dolomite speckles. This "salt-and-pepper" dolomite may represent algal mat structures. The black and white dolomite lenses are more numerous toward the west side of the middle unit. The black and white lenses apparently represent bedding and constitute the only megascopically recognizable planar feature for most of the apparent 4,600 foot thickness of the dolomite unit on Uncle Sam Mountain. The only obvious contact metamorphic effects of the Spirit pluton are a coarsening of grain size and bleaching, with some reported development of calcium silicates very near the contact with the pluton. The contact metamorphic effects received only cursory attention during the present mapping.

To the south the middle dolomite is not well exposed except for the south slopes of Baldy, Comstock, and the hills south-southeast of the Tenderfoot mine. On Baldy the middle unit is a massive, crystalline, white to gray dolomite containing some thin quartz veins. Some of the dolomite on Baldy is brecciated. The matrix is light-gray crystalline dolomite. Patches and irregular veinlets of quartz are present, and some of the quartz occurs as euhedral crystals up to 1 cm long. On Comstock the rock is, at least in part, a sandy, thin-bedded to laminated dolomite with bedding shown by variations in color from white to shades of gray. Some of the gray to dark-gray beds are dotted with white dolomite speckles very similar to the black and white dolomite lenses on Uncle Sam Mountain to the north. Some of the dolomite beds are creamy white and laminated, with bedding shown by variations in grain size. Beds are of inconsistent thickness and lateral extent; in some places, there are also beds defined by irregular layers composed of dolomite containing very irregular stringers and pods of hard, siliceous dolomite that stands in relief on weathered surfaces.

In places on Comstock, the laminated, sandy dolomite beds are broken, separated, and embedded in a massive to poorly bedded, sandy dolomite matrix. Matrix material is much more abundant than clasts, but bedding in the clasts and the longest dimensions of the clasts are parallel or sub-parallel to bedding. From the description and photograph given by Mills (1976, figure 54), it appears that the breccia exposed on the south flank of Comstock is the intraformational breccia defined by Yates (1964) as part of the middle member of the Metaline Limestone. If so, the intra-formational breccia is "a true sedimentary breccia developed by the breaking up of partially consolidated beds and the incorporation of the fragments in the new strata, which are nearly contemporaneous with the original beds" (Mills, 1976). Light- to dark-gray, sometimes very thin-bedded dolomite occurs on the south-facing slope of the hill in the southwest quarter of section 13, east of Comstock. Bedded areas are discontinuous as on Comstock, and the same kind of penecontemporaneous brecciation is prevalent. The rock is not nearly so recrystallized as that on Comstock. No zinc-lead mineralization was found in association with this breccia.

On the hills in the northeast quarter of section 26, about one-quarter of a mile south-southeast of the Tenderfoot mine, still another type of dolomite occurs. This is a bedded dolomite with bedding defined by laminations of hard, siliceous dolomite that are parallel to subparallel when viewed over an area of several feet. However, when seen in detail, the rock is a chaotic, rubbly mixture of fine crystalline dolomite and twisted, broken, or curved laminae of siliceous dolomite. Toward the east this type of dolomite grades into a dark-gray, finely-crystalline, massive dolomite. Toward the west the bedding in the dolomite becomes more regular and considerable zebra dolomite appears. Where seen together, the bands in the zebra dolomite and the bedding in the rock are parallel.

To the west of the hills south-southeast of the Tenderfoot mine and approaching the contact with the lower limestone unit, the rock changes from the bedded dolomite described above to black dolomite, to black, nearly massive, dolomitic limestone with brown-weathering partings, to black, argillaceous, fine-grained limestone. The black, argillaceous, fine-grained limestone is probably the uppermost part of the lower limestone unit, and is shown as such on figure 1.

The contact between the upper and middle units of the Metaline Limestone is not exposed. On Uncle Sam Mountain, the rocks on both sides of the contact appear to display minor folds, but whether this is an indication of faulting is not known.

The upper limestone unit of the Metaline Limestone crops out relatively well on the west end of Uncle Sam Mountain, but the only apparently undisturbed part of the unit crops out in the southwest quarter of section 2 and the southeast quarter of section 3. The upper unit here is a soft, nearly massive, light- to dark-gray, softly mottled, very fine-grained limestone with areas that contain small nodules up to about 1 inch in diameter of siliceous limestone. These siliceous nodules weather in slight relief. The nodules are often hollow in weathered cross-sections as if the core were limestone of about the same composition as the rest of the rock. Nowhere are these nodules abundant, but they are probably the same as the chert nodules referred to by Park and Cannon (1943, p. 18).

Near the Spirit pluton the upper unit is more coarsely crystalline, bleached, and dolomitized for up to about 200 feet from the contact.

A layer of dark-gray, crystalline dolomite, sometimes silicified, and up to at least 150 feet thick, occurs just below the Ledbetter-Metaline contact from the vicinity of the Hi Cliff mine southward to near the south one-sixteenth corner of the northeast quarter of section 10, a distance of about three-quarters of a mile. This dolomite appears to gradually grade downward into the soft, mottled limestone discussed above, apparently by a gradual decrease in magnesium content and degree of crystallization.

In the vicinity of the Neglected mine in section 1 the upper limestone is affected by generally north-, northeast-trending zones of sheeting and by a north-trending zone of breccia, in which small, angular, limestone breccia fragments are totally enclosed in a siliceous matrix. When the limestone fragments weather away, a siliceous, iron-stained honeycomb is left behind. The zones of sheeting and brecciation probably represent fault movements in the area around the Neglected mine, but no evidence was found to suggest that the upper limestone to the north or the Ledbetter Slate to the south and west were affected by these movements.

Structure

The lower limestone unit of the Metaline Limestone is clearly involved in folding on Uncle Sam Mountain. There the uppermost beds of the Maitlen Phyllite are exposed in the core of an overturned anticline. The east, upright limb of the fold strikes northeast and dips 40° SE., and the west, overturned limb strikes northeast and dips about 85° SE. There is some evidence that this fold or at least a similar fold continues to the south at least as far as the north one-half of section 24, where the east side of the belt of lower Metaline dips more gently toward the east-southeast than the west side of the unit, and minor folds are exposed near the center of the unit.

The nature of the middle dolomite unit seems to change from north to south. On Uncle Sam Mountain it is a fine to fairly coarse, crystalline, creamy-white, massive dolomite with lenses of black and white dolomite. To the south on Comstock and the hill east of Comstock, the rock is a thin-bedded dolomite or dolomite breccia with some siliceous laminae. South of the Tenderfoot mine the middle dolomite is a bedded dolomite or dolomitic limestone near the contact with the lower limestone unit. Outcrop is discontinuous in the Baldy-Comstock-Tenderfoot areas, and the different lithologies could exist as a bedded sequence with different parts exposed in different places. However, none of the common lithologies of the south end of the belt of middle dolomite is recognizable on Uncle Sam Mountain. Four possible explanations are suggested: The southern units may be folded out on Uncle Sam Mountain; contact metamorphism may have obliterated the bedding and breccia and homogenized the different lithologies; the different exposures may be separated by faults; or rapid facies changes might account for the changes in lithology. These possible explanations may be briefly examined. If the rocks of the southern part of the middle dolomite unit are actually present in the middle dolomite unit on Uncle Sam Mountain, it seems unlikely that recrystallization brought about by contact metamorphism could obliterate all traces of bedding and intraformational breccia and yet leave the lenses of black and white dolomite when all of these features are thought to represent original sedimentary or sedimentary-organic structures.

They all should have survived or been obliterated by contact metamorphism. Faulting and facies changes are harder to rule out because the covered intervals in valley bottoms and on north slopes leave plenty of room for faults, and also make it difficult or impossible to document facies changes. Folding is also difficult to demonstrate, but there are some points to recommend it. Folding has occurred in the Clugston Creek area. There is an apparent fold in the Metaline-Ledbetter contact on the south slope of Baldy. At the south end of the middle dolomite unit (south of the Tenderfoot mine), the lower and middle units of the Metaline Limestone are folded into an upright, south-plunging fold. This folding is demonstrated by the arcuate shape of the contact between the lower limestone and middle dolomite and by bedding attitudes in both units. If this fold involves the middle dolomite for its full length from Uncle Sam Mountain to the Tenderfoot mine area it might fold out parts of the middle unit, and at least partially explain the thickness of the middle dolomite on Uncle Sam Mountain, which is almost as great as the thickness reported for the entire Metaline Limestone in northern Stevens County (Yates and Robertson, 1958), Pend Oreille County (Dings and Whitebread, 1965), and British Columbia (Fyles and Hewlett, 1959).

Age

No fossils were found in the Metaline Limestone in the Clugston Creek area, except for graptolites in a contorted, tan shale block enclosed within the upper limestone unit and associated with the Josephine Breccia.

Trilobites were found in the lower limestone unit of the Metaline Limestone in Pend Oreille County by Park and Cannon (1943). These are Middle Cambrian in age.

ORDOVICIAN SYSTEM

LEDBETTER SLATE

Description

The Ledbetter Slate underlies the valley occupied by Clugston Creek and the south fork of Bruce Creek. The formation is best exposed in roadcuts, mine openings, and along the flanks of hills near contacts with more resistant rocks. Elsewhere, Ledbetter rocks underlie low-lying areas and have a mantle of glacial till and outwash deposits.

Thickness and Stratigraphic Relations

The Ledbetter Slate is relatively unaffected by metamorphism and tectonism along the eastern side of its outcrop area, but usually exhibits a slaty cleavage in addition to bedding. Farther to the west, the Ledbetter less often shows bedding and often has one and sometimes two directions of slaty cleavage.

Based on minimum outcrop width of each of the three informally recognized members, known folding, and assuming an average dip of 60° W., the minimum apparent thickness of the Ledbetter is 2,600 feet in the Clugston Creek area.

The base of the Ledbetter Slate is a sharply defined surface. Where the contact with the underlying Metaline Limestone is well exposed, the base of the Ledbetter is often slightly undulatory as if its basal beds were deposited on an uneven surface. The Ledbetter-Metaline contact is well exposed in a roadcut where the Clugston Creek road swings to the east around the northwest spur of Uncle Sam Mountain (near the center of section 3), in a roadcut about 500 feet west of the summit of Baldy, about 1,000 feet northwest of the lower adit of the Chloride Queen mine, and at the Tenderfoot mine.

Nevin (1942) lists eight evidences for faulting: Polishing and grooving (slickensides), fault breccia and gouge, sheet structure in rocks adjacent to faults, gash fractures, compression fractures, drag, fault scarps, and displacement of strata, veins, and dikes. At the four locations listed above where the Metaline-Ledbetter contact is well exposed, none of these features is developed. Over most of its length in the Clugston Creek area, the Metaline-Ledbetter contact is not a fault. However, near Baldy, along the middle part of the contact, there is some evidence for faulting. In the southwest quarter of section 11, red, iron-oxide-rich soils are present near the contact. The Ledbetter Slate is brecciated at one exposure near the contact, about 400 feet west of the center of section 14. A 28-foot-wide zone of brecciation was reported along the Metaline-Ledbetter contact in the eastern adit of the Big Chief mine, located at an elevation of 3,500 feet in the northeast quarter of the southwest quarter of section 14. If these indications represent faulting, that faulting is confined to the part of the Metaline-Ledbetter contact in section 14 and the southwest quarter of section 11.

The contact of the Ledbetter Slate with overlying Permian(?) eugeosynclinal rocks is not exposed. At one outcrop near the contact along the Clugston Creek road, the Ledbetter Slate is a brecciated, black, petroliferous-appearing slate. Based on this outcrop, the upper contact of the Ledbetter Slate is presumed to be a fault.

Lithology and Internal Relations

The Ledbetter Slate is informally divisible into three members in the Clugston Creek area. Where all of the lower member is present it has an apparent thickness of 1,500 feet. It is exposed only as far north as the west flank of Baldy, where it wedges out against the Metaline-Ledbetter contact. On the west ridge of Comstock, its thickness is about 800 feet; west of the Tenderfoot mine, its thickness is about 1,500 feet. Thickness increases toward the south at least as far as the Tenderfoot mine, but the lower member does not crop out south of there.

The lower member is predominantly argillite or slate. Near the contact with the Metaline Limestone the rock is often a little-disturbed shale. The argillites are generally dark colored and weather to shades of brown and red. They are often very thin-bedded or laminated, sometimes have a slaty cleavage, and are generally carbonate-free. The shales are usually black and noncalcareous, and weather black or shades of gray and brown. Bedding is sometimes indicated by variations in color or by the presence of fossils. Two directions of cleavage are sometimes developed.

Although the lower member is dominantly argillite or slate, carbonate beds are present and comprise 5 to 10 percent of the member. The carbonate beds are one-half inch to 20 feet in thickness, but are most commonly between 6 inches and 3 feet thick. Both limestone and dolomite beds are present, with the limestone beds somewhat more numerous than the dolomite beds; both are fine to very fine grained, generally dark-gray or black and argillaceous. The dolomite beds are sometimes hard and siliceous, sometimes contain quartz and calcite veins, and are sometimes broken. The limestone beds are often thin-bedded or laminated.

The lower member can be distinguished from other parts of the Ledbetter Slate by its higher proportion of argillite and shale as opposed to slate, and especially by the presence of carbonate beds. The upper contact of the member is placed at the base of the first quartzite beds in the middle member.

The middle member of the Ledbetter Slate has a maximum apparent thickness of 1,900 feet where it is exposed on the lower west flanks of Baldy and Comstock. South of Comstock exposures of the member are very few, but the member appears to thin rapidly to an apparent thickness of about 400-500 feet at the south end of the map area (figure 1). It is not known whether the apparent southward thinning of the member is due to tectonism or is an original sedimentary feature.

The middle member is dominated by argillite and slate, but layers of quartzite crop out most prominantly and appear to dominate when they actually account for no more than 25 percent of the member.

Argillite and slate occur in about equal proportions. The argillite is sometimes light brownish-gray or tan, but is usually gray, dark gray, or black. It is carbonate-bearing in a few places, weathers brownish-gray or tan, and is sometimes slaty. Bedding is sometimes indicated by color changes. As in the lower member, this rock seems to be less deformed near the contact with the underlying Metaline Limestone. The slate is almost always black, but occasionally is dark gray. It is noncalcareous, sometimes carries quartz veins up to 6 inches thick, and sometimes shows bedding which is indicated by brown-weathering laminae.

The middle member contains numerous quartzite beds, and the top and bottom of the unit are recognized by their first and last appearances. The quartzite beds are laminated to massive, very fine-grained (cherty?) to medium-grained, and are usually dark-gray to black but sometimes white, gray, pink or red in color. The quartzites sometimes carry a little calcite as cementing material, and range from a few inches to 150 feet or more in thickness. The thinner quartzite beds are usually very fine grained and the thick beds are coarser. One very thick quartzite bed on the lower west flank of Baldy greatly resembles parts of the Gypsy Quartzite (Early Cambrian). The quartzites sometimes carry quartz veins from 2 inches to 1 foot thick.

The upper member of the Ledbetter Slate in the Clugston Creek area appears to be at least 1,500 feet thick. It is poorly exposed along its west side, and uncertainty about the location of its contact with the overlying late Paleozoic eugeosynclinal rocks make this estimate very tentative. The upper member is the only part of the Ledbetter Slate that extends the full north-south length of the mapped area (figure 1). It crops out to the west of its contact with the Metaline Limestone and the Spirit pluton in section 3, and crops out here and there in roadcuts along the Clugston Creek and Weaver roads. Except for these few exposures, this part of the Ledbetter Slate is an area of generally low relief with an often extensive mantle of slope wash and alluvial and glacial materials. The upper contact is probably a fault, based on the occurrence of brecciated, petroliferous-appearing black slates in a roadcut near the contact along the Clugston Creek road in the southwest quarter of section 22. Wherever it is exposed, the lower part of the upper member is black slate with a generally well-developed slaty cleavage. When the cleavage is parallel to bedding, graptolites are commonly found; where bedding and cleavage are at an angle, which is usually the case, fossils are not found. Between 3,200 and 3,400 feet in elevation on the east slope of Aspend Hill, a few low outcrops of slaty, argillaceous, dark gray, occasionally laminated limestone were found. These seem to indicate that the upper part of the upper member is more calcareous than the rest of the formation. A similar observation was made by Dings and Whitebread (1965, p. 25) in part of the Metaline area of Pend Oreille County. The few outcrops of the upper part of the upper member in the Clugston Creek area do not allow any firm conclusions, however, because structure and stratigraphic relations are almost completely unknown.

Structure

One puzzling aspect of the Ledbetter Slate in this area is its greatly differing outcrop width and apparent thickness from place to place. If the upper contact is a fault, part of the Ledbetter may have been removed, and this would certainly change the apparent thickness of the formation. Folding may also be partly responsible. On the ridge to the southwest of the Tenderfoot mine, the lower member of the Ledbetter Slate has been at least partially repeated by folding. The lowest quartzite beds of the middle member crop out in the core of the fold.

The S-shape of the Metaline-Ledbetter contact on the south slope of Baldy is probably caused by folding. Minor folds were found at the northern end of the "finger" of Ledbetter that projects into the middle Metaline dolomite. However, brecciated Ledbetter was found at one location on the west side of the "finger" of Ledbetter and a 28-foot-wide breccia zone has been reported (Mills, 1976) at the Metaline-Ledbetter contact in the workings of the eastern adit of the Big Chief mine, near the east sixteenth corner of the southwest quarter of section 14, at about 3,500 feet in elevation.

The brecciated zones are no doubt an indication that some movement has taken place on this part of the contact. However, if a fault brought about the S-shape of the contact on the south slope of Baldy, the fault would have an apparent left-lateral displacement of at least 2,000 feet. A fault of this displacement should extend to the northeast and southwest for considerable distances, but no evidence of faulting has been seen on the surface to the northeast, and none is recorded on the mine-map of the Big Chief western adit, which is collared in the valley of the north fork of Clugston Creek just south of Baldy. Instead there is a zone of considerable folding in the Ledbetter from about 150 feet to about 700 feet in from the portal of the east-southeast-trending adit. This zone of folding in the Big Chief workings aligns with the projection of middle Metaline dolomite on the south slope of Baldy. Available evidence considered, folding is more likely the cause of the S-shape in the Metaline-Ledbetter contact than faulting.

The thick quartzite in the Ledbetter on the lower west slope of Baldy also gives some indication of folding. At its south end, it appears to strike north-northeast and dip very steeply, but at its north end the outcrop swings toward the west and broadens. Bedding at the north end strikes 155° and dips 45° SW.

In addition, many outcrops of the Ledbetter have a well-developed, near vertical to moderately west-dipping slaty cleavage that is probably the axial plane cleavage for a set of folds. Some outcrops show two directions of slaty cleavage, and these probably indicate that the rocks have been folded twice. It seems unlikely that either of these episodes of folding has acted on a scale that involves the entire Ledbetter in a single fold because the three members have not been repeated as a whole. However, it is certain that the lower member has been at least partially repeated by a fold southwest of the Tenderfoot mine, and many other relatively small folds might occur that could, cumulatively, increase the apparent thicknesses of the three members of the Ledbetter Slate.

Age

Graptolites have been found in all three members of the Ledbetter Slate in the Clugston Creek Area. Trilobites were found at one locality near the Tenderfoot mine. Fossil localities are identified by an "F" on figure 1. Those localities from which fossil collections have been examined and an age assigned are identified by an "F" and the field number assigned to each locality. Identified fossils are listed in table 1.

Graptolites have been found in the Ledbetter in Stevens and

TABLE 1.—Fossils from Ledbetter Slate in the Clugston Creek area, Stevens County, Washington

Identified fossils \ Fossil localities	71-105[1/]	73-26[2/]	75-9[3/]	75-5[4/]	75-50[5/]	72-430[6/]
Graptolites:						
Climacograptus eximius	x					
Climacograptus spp. (poorly preserved specimens cf. *C. phyllophorus* and *C. modestus*)	x					
Climacograptus spp.		x				
Cryptograptus tricornis	x					
Dicellograptus cf. *D. gurleyi*	x					
Dicellograptus sextans	x					
dichograptid fragments				x	x	
Dicranograptus sp. (cf. *D. nicholsoni* var. ?)	x					
Didymograptus sp. (pendent form—possibly of *D. bifidus* group)				x		
Didymograptus sp. (pendent form of the *D. bifidus*—*D. protobifidus* type)					x	
Didymograptus sagitti caulis	x					
Diplograptus?	x					
Glyptograptus sp.	x	x				
Glossograptus cf. *G. acanthus*			x			
Glossograptus hincksii	x					
Hallograptus?	x					
Isograptus sp. of the *I. victoriae* type—possibly *I. victoriae divergens*			x			
leptograptid or dicellograptid stipe fragments		x				
Orthograptus calcaratus acutus?	x					
Orthograptus of the *O. truncatus* type?		x				
Phyllograptus sp.			x	x		
Reteograptus geinitzianus	x					
Tetragraptus cf. *T. serra*?				x		
Crustacean:						
Caryocaris sp.						x
Trilobites:						
Bienvillia sp.						x
Hystricurus aff. *H. genalatus* Ross						x
Sponge:						
sponge spicules						x

1/ Northwest spur of Uncle Sam Mountain east of center section 3 (37-39E).
2/ Neglected mine south end of NW¼ section 11 (37-39E).
3/ West flank of Baldy, north end of NW¼ section 14 (37-39E).
4/ Southeast flank of Baldy, east 1/16 corner NW¼, section 14 (37-39E).
5/ West spur of Comstock, north end of NW¼ section 23 (37-39E).
6/ Tenderfoot mine, west 1/16 corner SE¼ section 23 (37-39E).

TABLE 2.- CORRELATION WITHIN THE ORDOVICIAN SYSTEM

AGE		ENGLAND (STAGES)	UNITED STATES (STAGES)	GRAPTOLITE ZONES OF THE MARATHON REGION, TEXAS	HUDSON RIVER VALLEY, NEW YORK
ORDOVICIAN SYSTEM	LATE	ASHGILL	RICHMOND	*DICELLOGRAPTUS COMPLANATUS* ZONE 15	
		CARADOC	MARYSVILLE EDEN	*ORTHOGRAPTUS QUADRIMUCRONATUS* 14	
	MIDDLE		TRENTON	*O. TRUNCATUS VAR. INTERMEDIUS* 13	CANAJOHARIE
			WILDERNESS	*CLIMACOGRAPTUS BICORNIS* 12	NORMANSKILL
			PORTERFIELD	*NEMAGRAPTUS GRACILIS* 11	
		LLANDEILO	ASHBY	*GLYPTOGRAPTUS* cf. *G. TERETIUSCULUS* 10	
		LLANVIRN	MARMOR	*HALLOGRAPTUS ETHERIDGEI* 9	DEEPKILL
			WHITEROCK	*ISOGRAPTUS CADUCEUS* 8	
				DIDYMOGRAPTUS BIFIDUS 7	
	EARLY	ARENIG	CANADIAN SERIES	*D. PROTOBIFIDUS* 6	DEEPKILL
				TETRAGRAPTUS FRUTICOSUS 3 and 4 branched 5	
				T. FRUTICOUS 4 branched 4	
				T. APPROXIMATUS 3	
		TREMADOC		*CLONOGRAPTUS* 2	
				ANISOGRAPTUS ZONE 1	SCHAGHTICOKE

ADAPTED FROM BERRY, WILLIAM B.N., 1962, STRATIGRAPHY, ZONATION, AND AGE OF SCHAGTICOKE, DEEPKILL, AND NORMANSKILL SHALES, EASTERN NEW YORK; GEOLOGICAL SOCIETY OF AMERICA BULLETIN, V. 73, P. 710.

Pend Oreille Counties, Washington, or its equivalent in Canada by several geologists (Park and Cannon, 1943; Little, 1960; Yates and Robertson, 1958; Yates, 1964, 1971), and some of these fossils have been assigned Early and Middle Ordovician ages. Likewise the graptolites from the Clugston Creek area are Early and Middle Ordovician in age. Three collections from the west slope of Baldy, the southeast slope of Baldy, and the west spur of Comstock (field localities 75-9, 75-5, and 75-50, respectively) yielded graptolites that are probably from Berry's zones 7-8, 6-7, and 6-7, respectively. Zones 7 and 8 are earliest Middle Ordovician, and zone 6 is latest Early Ordovician (table 2). These three fossil localities are in the lower or lower middle members of the Ledbetter Slate in the Clugston Creek area.

Locality 71-105, in a roadcut at the base of the northwest spur of Uncle Sam Mountain, yielded graptolites that are probably from zones 11-12, corresponding to the upper part of the Middle Ordovician. This locality is in the upper member of the Ledbetter Slate. All graptolite collections were made by the author, examined by Dr. William B. N. Berry, of the Department of Paleontology, University of California at Berkeley, and reported in Dr. Berry's letters dated September 19, 1975, and November 19, 1975.

Graptolites were found in the Ledbetter Slate in the Clugston Creek area by W. A. G. Bennett (1937). These fossils were identified by Ruedemann (1947) as Early and Middle Ordovician in age. Unfortunately, no record remains of exactly where Dr. Bennett made his collections.

Trilobites were found by the author in the lower member of the Ledbetter Slate at the Tenderfoot mine in 1972 and subsequently (field locality 72-430). No mention has been made in the Canadian or U.S. literature of trilobites from the Ledbetter Slate, so this is presumed to be the first known occurrence. The fossils were found in a light- to medium-gray, planar laminated, noncalcareous mudstone or shale with molds of limonite after pyrite and iron-oxide staining on weathered surfaces. The fossils were contained in rock from within 20 feet of the Ledbetter-Metaline contact immediately southwest of the Tenderfoot mine workings. They were found in rubble pushed out during construction of the access road to workings south of and up the hill from the Tenderfoot mine. Identified fossils are listed in table 1.

The trilobites were identified by Dr. Michael E. Taylor, Paleontology and Stratigraphy Branch, U.S. Geological Survey, U.S. National Museum, Washington, D. C. The fossils from 72-430 were described as follows in Taylor's letter of March 2, 1976.

Locality 72-430 contains the trilobites *Bienvillia* sp. (the olenid of my earlier letter of March 13 and July 1, 1975) and *Hystricurus* aff. *H. genalatus* Ross, 1951. *H. genalatus* is known from the Lower Ordovician, lower Garden City Formation (trilobite zone B) of northeastern Utah, the House Limestone (trilobite zone B and C) of western-central Utah, and the Goodwin Limestone (pre-Trilobite zone G) of central Nevada. *Bienvillia* is known from the Upper Cambrian and Lower Ordovician (Tremadocian and Arenigian Series) of western Europe, North America, and South America. The species present, which is probably new, is most similar to Tremadocian species rather than Upper Cambrian or Arenigian species (see table 2).

Locality 72-430 also contains abundant sponge spicules and the phyllocarid crustacean cf. *Caryocaris* sp. *Caryocaris* is known from the Road River Formation of east-central Alaska; graptolitic shales at Garden Pass, central Nevada; Trail Creek, Idaho; Antelope Range, central Nevada; and the Marathon Basin, Texas. Some paleontologists have considered *Caryocaris* to be Ordovician in age and probably restricted to the lower half of the System. However, the Antelope Range occurrence could be Upper Cambrian. This evidence plus the fact that all known occurrences are associated with offshore dark shales and/or cherts, suggests that emphasis should not be placed on *Caryocaris* in making biostratigraphic correlations.

In sum, the faunal data support an Early Ordovician age for locality 72-430. The critical evidence is the presence of *Hystricurus* aff. *H. genalatus* which is known only from the Lower Ordovician.

These trilobite data plus Bill Berry's graptolite data support your interpretation that the base of the Ledbetter is younger from south to north if beds have not been faulted out near the contact in more northerly sections.

The progressively younger age of the Ledbetter Slate at the Ledbetter-Metaline contact from south to north in the Clugston Creek area, the wedging out northward of the lower two members of the Ledbetter Slate, and the lack of evidence for faulting everywhere, except in the vicinity of Baldy where the contact is folded, all suggest that the Ledbetter Slate is an onlapping formation and probably is the product of deposition in a transgressive sea.

JOSEPHINE BRECCIA

The Josephine Breccia is developed just beneath the Ledbetter Slate-Metaline Limestone contact from near the center of section 3 southward for about 4 miles to the Tenderfoot mine in the south one-half of section 23. The Josephine Breccia is not to be confused with the penecontemporaneous breccia in the middle dolomite unit. The Josephine Breccia is developed through different thicknesses of Metaline Limestone from place to place, and does not occur everywhere as a zone beneath the Ledbetter occupied solely by breccia. The part of the Metaline Limestone in which the Josephine Breccia lies may be described as a variable thickness of carbonate rock, some apparently unchanged from lithologies found elsewhere in the Metaline Limestone, that contains erratic brecciated zones. At the Hi Cliff mine in section 3 the Josephine Breccia occurs in the underground workings, but on the surface there is a 150 foot-wide zone of fine-grained, medium-gray massive dolomite beneath the Ledbetter-Metaline contact, and this dolomite grades into undisturbed limestone of the upper limestone unit. Josephine Breccia was not observed on the surface. In contrast, at the Neglected mine, the Josephine Breccia is well developed at a map distance of about 1,300 feet from the nearest part of the Ledbetter-Metaline contact, and the stratigraphic distance beneath the contact appears to be about 900 feet.

The Josephine Breccia in the Clugston Creek area usually has a matrix of light gray or cream-colored, massive, crystalline dolomite. Small areas at the Tenderfoot mine and on the west slope of Baldy exhibit dark-gray, finely crystalline dolomite and black, massive, very fine-grained quartz (jasperoid?) matrices, respectively.

Fragments in the breccia are subangular to subrounded, almost completely surrounded by the matrix, entirely unsorted, and the fragments range in size from less than a few millimeters to at least one meter. Most of the breccia fragments are dolomite. Fragments may be black dolomite, silicified dolomite, creamy-white dolomite, bedded dolomite, or black dolomite with white speckles. Small chips of black argillite, black silicified argillite, or slate are common and conspicuous, but makeup only a small percentage of the breccia fragments. Sometimes these chips are elongated and angular with lengths up to at least 6 inches and thicknesses of only one-half inch. At the Tenderfoot mine, all of the above lithologies are present in the breccia. At the Meyer adit on Comstock, most of the fragments are creamy white or dark-gray, bedded to massive crystalline dolomite. Quartz stringers and veinlets are common in the matrix, and sometimes quartz crystals are present. Galena occurs as nodules in the matrix. At the Meyer adit, the matrix is coarser grained than the fragments.

At the Neglected mine, tan, bedded shale occurs in the Josephine Breccia. The tan shale occurs as thin pods and as irregular blocks up to 4 feet across in which the bedding is contorted. These pods and blocks of tan shale contain Ordovician graptolites. Here the Josephine Breccia fragments are both limestone and dolomite, and the matrix is coarse-grained, light-gray to white dolomite with a little galena and sphalerite. The significance of the graptolites will be discussed below.

Other blocks of tan shale were found in the Metaline Limestone in the northeast quarter of section 10. In the same area the limestone is often brecciated and carries brown- to reddish-weathering stringers of argillite. In some places the argillite stringers make up 50 percent of the rock, and the stringers are sometimes very irregular, almost vermiform, and often have cores of lath-shaped crystalline quartz. In this breccia the fragments are all limestone, have not been rotated, and the breccia grades into undisturbed soft, mottled gray, nearly massive limestone over distances of at least 100 feet. This breccia might be a transitional form between well-developed Josephine Breccia and undisturbed upper Metaline Limestone.

DISCUSSION

The origin of the Josephine Breccia has puzzled geologists since Park and Cannon mapped the Metaline quadrangle in 1943. Park and Cannon (1943) and Dings and Whitebread (1965) consider the Josephine a tectonic breccia. McConnell and Anderson (1968) consider it a sedimentary breccia. Mills (1976) has reviewed all of the characteristics of the Josephine Breccia and considers it a solution-collapse breccia.

In the Clugston Creek area, the Josephine is not a fault breccia because the Metaline-Ledbetter contact, beneath which it is developed, is not a fault over most of its length. As described earlier, the Ledbetter Slate near the Metaline-Ledbetter contact displays no evidence of faulting whatever, except in the vicinity of Baldy. Likewise, the

Josephine Breccia and Metaline Limestone near the contact fail to display widespread evidence of faulting. Brecciation and cellular networks of quartz and sheeting are developed in the south end of the belt of upper Metaline strata around the Neglected mine, and faulting is reported in the underground workings of several of the mines and prospects. However, if the Josephine Breccia developed as a result of faulting, evidence of faulting should be abundant over its entire outcrop length, which is clearly not the case.

If the Josephine Breccia is a conformable sedimentary unit deposited at the close of the deposition of the Metaline Limestone it should lie parallel to the bedding in the underlying Metaline Limestone, and it should always be found at the same stratigraphic level. In the Clugston Creek area, the Josephine clearly crosscuts the bedding, for it lies on the truncated edges of both the upper limestone and middle dolomite units of the Metaline Limestone.

Since the Josephine Breccia clearly crosscuts bedding in the underlying Metaline Limestone, and the Metaline-Ledbetter contact is not a fault, the Josephine Breccia is probably related to the angular unconformity beneath which it lies. Its origin as a solution-collapse breccia fits very well with field data from the Clugston Creek area, and Mills (1976) has convincingly demonstrated that this origin applies to the Josephine Breccia throughout Stevens and Pend Oreille Counties.

The Ordovician graptolites (table 1) found in tan shale well within the upper limestone unit of the Metaline Limestone at the Neglected mine offer further proof that the Josephine Breccia is of solution-collapse origin. The tan shale is within the Josephine Breccia at the Neglected mine, and there is no evidence whatever to suggest that faulting is responsible for its emplacement. If faulting did not place the Ordovician tan shale within the Cambrian Metaline Limestone, then it must have been transported there through openings in the Metaline Limestone. Creation of openings through the formation of a karst terrain appears quite possible: plenty of time was apparently available between the close of Metaline Limestone deposition in Middle Cambrian time and the beginning of Ledbetter Slate deposition in early Ordovician time (the oldest gratolites found near the contact in the Clugston Creek area are late Early Ordovician in age, but the trilobites from the Tenderfoot mine area might be early Early Ordovician), and the Metaline Limestone had certainly been folded and had an erosion surface developed on it before Ledbetter Slate deposition began.

Furthermore, the tan shale at the Neglected mine is in blocks as large as 4 feet across, the bedding in the blocks is well developed but contorted, and the blocks are poorly lithified. It is difficult to see how such large blocks of poorly lithified shale could have been transported a map distance of 1,300 feet and an apparent stratigraphic distance of 900 feet into the Metaline Limestone from the nearest Ledbetter Slate above the contact without disintegrating. If the blocks had been lithified, disintegrated, and then deposited in a cavern as loose sediment, the graptolite fossils could never have survived the journey. Rather, it seems necessary to suppose that loose sediment and living or just-deceased graptolites were carried downward into the Metaline Limestone at the time the Ledbetter Slate was being deposited, and were deposited in a cavern as a bedded shale containing graptolites.

The above interpretation means the cavern system that was the progenitor of the Josephine Breccia was in existence by late Middle Ordovician time—and that the cavern system was developed to an apparent depth of 900 feet stratigraphically below the Metaline-Ledbetter contact. This interpretation, however, does not preclude further development of the cavern system at a later date when the part of the Metaline Limestone lying just below the Metaline-Ledbetter contact might have again served as an aquifer.

CONCLUSIONS

1. The contact between the Ledbetter Slate and the Metaline Limestone is a pronounced angular unconformity. Strata of the Ledbetter Slate rest on the upper, middle, and possibly the lower units of the Metaline Limestone within a map distance of about 3 miles and a distance along the contact of less than 5 miles. Erosion may have removed a stratigraphic thickness of about 5,500 feet from the Metaline Limestone in the vicinity of the Tenderfoot mine.

2. The Metaline Limestone was folded before the Ledbetter Slate was deposited.

3. The Ledbetter Slate is an onlapping formation. Its basal beds are older (perhaps as old as early Early Ordovician) at the south end of the Clugston Creek area near the Tenderfoot mine and younger (middle

Middle or upper Middle Ordovician) at the north end of the area. The lower two of the three informally recognized members of the Ledbetter Slate terminate against the Ledbetter-Metaline contact.

4. Folding occurred after deposition of the Ledbetter Slate. This is demonstrated by the fold in the Ledbetter-Metaline contact on the south slope of Baldy.

5. The Metaline-Ledbetter contact is not a fault except possibly in the vicinity of Baldy.

6. The Josephine Breccia, of solution-collapse origin, is found in an irregular, discontinuous zone just beneath the Ledbetter-Metaline contact for an apparent stratigraphic distance of up to 900 feet. It is developed in the upper limestone and middle dolomite units of the Metaline Limestone.

7. Because the Metaline Limestone is topped by a pronounced angular unconformity, it would be unwise to restrict exploration for Josephine Breccia-type zinc-lead deposits to areas where the Ledbetter rests on upper Metaline rocks as would be done if it is assumed that the Josephine Breccia is of sedimentary origin and lies at a consistent stratigraphic level at the top of the Metaline Limestone. Exploration should encompass a stratigraphic thickness of carbonate rocks, whether upper, middle, or lower Metaline, of at least 1,000 feet below the Metaline-Ledbetter contact because the Josephine Breccia, the major host rock for zinc-lead deposits in Stevens and Pend Oreille Counties, owes its existence to the overlying unconformity and is developed in at least two of the three Metaline Limestone units.

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