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STRATIGRAPHIC RELATIONSHIPS OF THE COWLITZ FORMATION, UPPER NEHALEM RIVER BASIN, NORTHWEST OREGON

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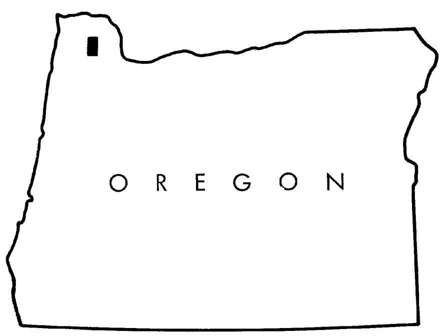
Introduction

The stratigraphic relationships of the Cowlitz Formation to late Eocene volcanic rocks and to the overlying Keasey Formation in the upper Nehalem River basin have been unclear in the past owing to lack of detailed study. Mapping of these units by the writer was completed in 1970 as part of a doctoral dissertation on the sedimentary petrology of the upper Nehalem River basin (Van Atta, 1971). The refinements in understanding of the stratigraphy proposed in this paper are the result of petrologic analysis of the formations exposed in this area.



Location of map area

In the upper Nehalem River basin of northwest Oregon (see Plate I), the late Eocene and Oligocene argillaceous marine sediments of the Cowlitz and Keasey Formations and the basalts of the Goble Volcanics are well exposed. Numerous small, deeply incised creeks with fairly high gradients provide good outcrops. Intensive logging activity has made nearly every part of the area accessible by roads and has provided numerous road cuts with large exposures. Several quarries and the recent widening of U.S. Highway 26 have furnished additional exposures of value in interpreting the local stratigraphy.

Previous Work

Warren, Norbisrath, and Grivetti (1945) published a geologic map of northwestern Oregon which included the area of this present study.

Although 22 15-minute quadrangles covered by their study were mapped in just 1½ years (P. D. Snavely, Jr., personal communication, 1962), the mapping is high in quality. They applied the name Goble Volcanic Series to the volcanic rocks along the Columbia River and noted an interfingering relationship between the Goble rocks and the sedimentary Cowlitz Formation in that area. In mapping the upper Nehalem River basin, however, they included similar late Eocene volcanic rocks in the Tillamook Volcanic Series, a unit which they believed to lie unconformably beneath the Cowlitz Formation.

Warren and Norbisrath (1946) elaborated more fully upon the stratigraphy of the upper Nehalem River basin, but made no refinements of the stratigraphic relationships between the Cowlitz Formation and the late Eocene volcanic rocks of the Tillamook Volcanic Series. In that paper, they delineated the contact between the Cowlitz Formation and the overlying Keasey Formation on the basis of megafauna and microfauna.

In 1953, Deacon, in an unpublished master's thesis, proposed a revision of the upper Eocene and lower Oligocene stratigraphy of the upper Nehalem River basin based upon the lithology of the Tertiary sedimentary rocks exposed in the area. Deacon redefined the Cowlitz and Keasey Formations, substituting the name "Rocky Point formation" for the Cowlitz and introducing the name "Nehalem formation" for parts of the lower member of the Keasey Formation.

Purpose of Present Study

The purpose of this paper is to clarify the relationship between the Cowlitz Formation and the late Eocene volcanic rocks of the western part of the upper Nehalem River basin by showing that the youngest part of the Tillamook Volcanic Series of Warren and others (1945) is the Goble Volcanics member of the Cowlitz Formation. Because there is only a slight lithologic distinction between the lower member of the Keasey Formation and Warren and Norbisrath's (1946) "upper shale member" of the Cowlitz Formation, it is suggested that the "upper shale member" of the Cowlitz Formation be included in the Keasey Formation.

Stratigraphy

Cowlitz Formation

The oldest sedimentary unit in the area of this study consists of conglomerate, sandstone; siltstone, mudstone and intercalated volcanic rocks. According to Warren and others (1945) and Warren and Norbisrath (1946, p. 221), the sediments contain a fauna correlative with that of the type Cowlitz Formation in southwestern Washington. These workers informally divided the Cowlitz Formation in the upper Nehalem River basin into four members: a basal conglomerate member, a lower shale member, a sandstone member, and an upper shale member. It should be noted, however, that none of the rocks in either shale member show fissility and therefore do not fit the definition of shale as given by Twenhofel (1937), Williams and others (1954), and Pettijohn (1957). According to the classification of Folk (1968), all such rocks of the "lower shale member" (siltstone member of this report) are siltstones and all those of the "upper shale member" (lower member of Keasey Formation of this report) are mudstones.

In view of the detailed study of the petrology of the Cowlitz Formation and the writer's interpretation of the stratigraphic relationships of the lithologic units which are included in this formation (Van Atta, 1971), it is proposed that the Cowlitz Formation be divided into three members: a siltstone member, an overlying (?) sandstone member, and the interfingering Goble Volcanics member. Basaltic flows, breccias, sills, and dikes of the Goble Volcanics member are present in both the siltstone and the sandstone members. The evidence supporting these conclusions is presented below.

Siltstone member: In roadcuts along the Sunset Highway west of Timber Junction, exposures of siltstone and sandy siltstone termed the "lower shale member of the Cowlitz Formation" by Warren and Norbisrath (1946, p. 223) crop out. Additional exposures westward along the Sunset Highway indicate that in many places the siltstone is interbedded with basaltic flows and breccia, basaltic conglomerate, and volcanic sandstone. It is concluded that conglomerate is recurrent throughout much of the section and does not represent a basal unit in the Cowlitz Formation as postulated by Warren and Norbisrath (1946).

Characteristically basaltic conglomerates are closely associated with the basaltic flows and breccias from which they were presumably derived. Conglomerate grades laterally away from the volcanics into volcanic sandstone, which in turn passes into the siltstone which constitutes the bulk of the lower part of the Cowlitz Formation. An easily accessible exposure showing these relationships is present along the Sunset Highway 2.2 miles west of the Washington-Tillamook County line.

The character of the conglomerate varies greatly from locality to locality. West of Timber, Oregon it is reported to be over 200 feet thick and composed of poorly sorted sand with basaltic pebbles, cobbles, and a few basalt boulders up to 8 feet in diameter (Warren and Norbisrath, 1946, p. 223). This appears to be exceptional, however, since all other occurrences of conglomerate are no more than 10 to 20 feet thick. Along Lousignont Creek Road (S$\frac{1}{2}$ sec. 18, T. 3 N., R. 5 W.) a few feet of sandy conglomerate grades laterally into greenish volcanic litharenite (classification of Folk, 1968). In other places, such as at the small Columbia County quarry on the Nehalem River a bouldery pebbly conglomerate lense, which grades upward and laterally into sandy siltstone, is intruded

Figure 1. Peel of arkosic sandstone from Cowlitz Formation, Clear Creek. Upper 14 inches cross-laminated with abundant muscovite mica flakes oriented parallel to planes of laminae, which are nearly horizontal. A large burrower hole is seen in the upper left. The lower 20 to 21 inches is indistinctly laminated with 12 to 15 inch cross-laminae. Numerous clots of sand (darker), in which mica is in random orientation, are probably due to activity of burrowing organisms.

by a basaltic sill. Other such relationships are more fully described below in the discussion of the Goble Volcanics member of the Cowlitz Formation.

Because the base of the siltstone member does not appear to be exposed in the area of this study and because of low angles of dip and uncertain correlation, no measurement of thickness was attempted. It is improbable that the siltstone member of the Cowlitz Formation is more than a few hundred feet thick, however.

Sandstone member: Warren and Norbisrath (1946) described a "gray, fine- to medium-grained, micaceous" sandstone which "contains much fragmentary plant material," which they regarded as overlying their "lower shale member" (siltstone member of this report) of the Cowlitz Formation. Stratification is described as fair but cross-bedding and ripple marks are said to be rarely seen (1946, p. 223). They point out that shell fragments are rare and they do not mention other fossils. Typical outcrops are considered by these workers to be exposed along the Nehalem River near Rocky Point and west of Timber. They also mention sandstone along the Nehalem River south of the bridge on the Sunset Highway. For the most part, the lithology of samples taken from the east end of Rocky Point correspond with the descriptions of Warren and Norbisrath.

Numerous cuts along logging roads west of the Nehalem River from Keasey to Rocky Point, in the Clear Creek drainage area, southwest of the Timber-Vernonia junction, and in the Lousignont Creek drainage area expose gray, micaceous, carbonaceous, cross-bedded, arkosic to lithic, silty sandstone interbedded with gray, well-stratified, sandy siltstone, claystone, and some pebbly sandstone. The sandstone is less than 10 percent volcanic glass, is poorly indurated, contains no cement and has only rare concretions. The siltstone is finely laminated with some disrupted laminae and much cut-and-fill structure. The arkosic sandstone in this region resembles littoral or sublittoral sands in both structure and texture (see Figure 1). It differs from the sandstone described by Warren and Norbisrath (1946) farther to the east in that it contains less brown plant debris, less clay, fewer concretions, and is distinctly a lighter gray. No fossils were observed in any of the beds of this member.

The sandstone and interbedded siltstone constitute an easily recognizable member of the Cowlitz Formation. Structural complexity and the lack of certain correlation between outcrops make measurement of thickness difficult. On the basis of present data, Warren and Norbisrath's (1946, p. 224) estimate of 200 to 300 feet appears reasonable.

Although much primary structure is present in the sandstone member, it is generally obscure; however, it is readily observed in peels taken from fresh exposures. In preparing the peels for this study, the methods of Bouma (1969, p. 1-83), as described by Van Atta (1971, p. 46-48), were followed.

Where the rock outcrop is a uniform gray, lamination and grading can be detected only by careful observation, but peels from such exposures show laminae (0.25 to 1.0 cm thick) which are delineated by the presence

Figure 2. Arkosic sandstone with aligned claystone clasts (darker) in sandstone member of Cowlitz Formation. (Clear Creek)

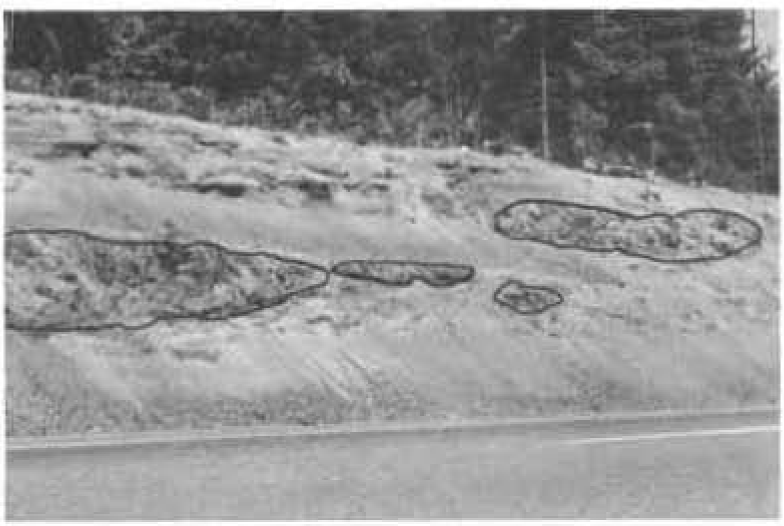


Figure 3. Pebble conglomerate in lower Cowlitz Formation with included blocks and slabs of basalt of Goble Volcanics. U.S. Highway 26, 2.2 miles west of Washington-Tillamook County line.

of much mica and/or finely comminuted plant debris or by fine-scale grading.

Peels reveal that low-angle (a few degrees to 10°) cross-lamination is common, ranging from a few inches to 14 inches in length. Foreset laminae are locally observed with inclinations up to 40°. Current directions range from southeast to southwest; however, lack of stratigraphic correlation between outcrops makes interpretation of these data questionable. Many sets of cross-laminated beds contain scour channels. Laminated siltstone peels from one locality show much contortion and separation of laminae. Although it is possible that the siltstone is a turbidite, such contorted features probably resulted from load deformation.

Another feature seen in peels, but not in outcrops, are borer holes represented by tubes filled with sediment containing unoriented mica flakes or mud (see Figure 1). The holes do not greatly disrupt the bedding.

At several localities two or three bands containing angular silty claystone clasts from 0.5 to 3.0 inches in size are inter-stratified with beds of fine- to medium-grained, cross-laminated, micaceous sandstone. The bands containing the claystone clasts resemble intraformational breccia, except that the clasts are restricted to distinct strata rather than being scattered throughout the sandstone (see Figure 2).

Collectively the primary structures suggest a littoral to shallow marine environment with moderate current action and a moderate sediment supply. Benthonic organisms were also present, suggesting non-toxic bottom conditions. Interbedded siltstone and minor amounts of mudstone within the sandstone member indicate environmental variations both in place and time during deposition.

Almost without exception beds within the sandstone member of the Cowlitz Formation strike northwest to west and dip south to southwest. Reversals in dip within the sandstone member were measured just west of the Timber-Vernonia junction and between Keasey and Rocky Point where dips are to the northeast and east. From attitudes at the Timber-Vernonia junction outcrop it would appear that the sandstone member underlies exposures of the siltstone member which are situated along the Sunset Highway. Further study and more supporting data would be required to substantiate this interpretation, and the view that the siltstone member underlies the sandstone member is adhered to in this report. It is also possible that the sandstone member interfingers with the siltstone member.

The strike of the younger beds of the Tertiary section in the upper Nehalem basin (Keasey Formation) is consistently northeasterly and dips are southeasterly. Strikes displayed by the sandstone member of the Cowlitz Formation are then opposed to the strike of all the younger strata in the area by angles varying from 45° to 90°. This discordance may be indicative of an unconformity between the sandstone member of the Cowlitz Formation and the overlying mudstone. However, Baldwin (oral communication, 1970) states that local warping similar to that which is common throughout the Coast Range could also account for the relationship.

Figure 4. Fan jointing in basalt intrusion (Goble Volcanics) with overlying siltstone, sandstone member, Cowlitz Formation. (Clear Creek, NW 1/4, sec. 28. T. 4 N., R. 5 W.)

Figure 5. Laminated mudstone inclusion (lighter tone) in basalt. (Same location as Figure 4)

Goble Volcanics member: Warren and others (1945) applied the name Goble Volcanic Series to basic flows and pyroclastic rocks which interfinger with tuffaceous sediments of the Cowlitz Formation along the Columbia River north of the upper Nehalem River basin. In the type locality of the Cowlitz Formation, Henriksen (1956, p. 59) reports, "Since the Goble Volcanics are relatively thin here [in the eastern Willapa Hills area, southwestern Washington] and are interfingered with sediments of the Cowlitz Formation [the Olequa Creek member] it is considered justifiable to lower the rank of the Goble Volcanics to a member in this area." Since a similar relationship is apparent in the upper Nehalem River basin, the Goble Volcanics are here referred to as a member of the Cowlitz Formation.

As noted above, in every outcrop consisting of interbedded sedimentary rock and basaltic flows and breccias of the Goble Volcanics member, transitional boulder to pebble conglomerates are also present. The best examples of these relationships can be seen along the Sunset Highway from the Washington-Tillamook County line westward. Road cuts near the county line reveal basaltic flows interfingering with a thin pebble conglomerate which contains subangular basalt boulders. Siltstone and sandstone beds underlie the interbedded lavas and conglomerate. Just south of the highway (center sec. 6, T. 3 N., R. 5 W.) basaltic lava is overlain by 3 to 4 feet of fossiliferous pebble conglomerate and pebbly sandstone composed largely of claystone clasts. On the south side of the highway 2.2 miles west of the Washington-Tillamook County line, a pebble conglomerate rests with a very irregular and steeply dipping contact upon late Eocene basalts of the Goble Volcanics. On the north side of the highway at this locality, there is about 12 feet of pebble conglomerate and claystone containing subangular and rounded blocks of basalt 4 to 5 feet in diameter (see Figure 3). Some blocks have a faint suggestion of pillow structure and contain pyrite, zeolites, and calcite on fracture surfaces and in vugs and veins.

In the sandstone member of the Cowlitz Formation the Goble Volcanics occur generally as dikes and sills which were apparently injected into wet, semiconsolidated sediments. Pillow structure and palagonite, extensive silicification, zeolitization, and pyritization of superjacent sediments are common features in basalt bodies exposed in several quarries in the Clear Creek drainage area. (See Figures 4, 5, and 6)

Additional exposures in which the intrusive relationships are displayed include those at the Columbia County quarry near the Nehalem River, at Rocky Point, and at the ridge crest of Rocky Point. In the Columbia County quarry a basaltic sill appears to be intrusive between an underlying bentonitic, pyritic, silicified mudstone and overlying bouldery pebble conglomerate (see Figures 7 and 8). This exposure has been interpreted by others as a basaltic flow or flows (for example, Deacon, 1953, p. 77). However, the presence of pyrite, zeolites, and calcite in both the upper part of the sill and in the overlying conglomerate, and the thin hydrothermally altered

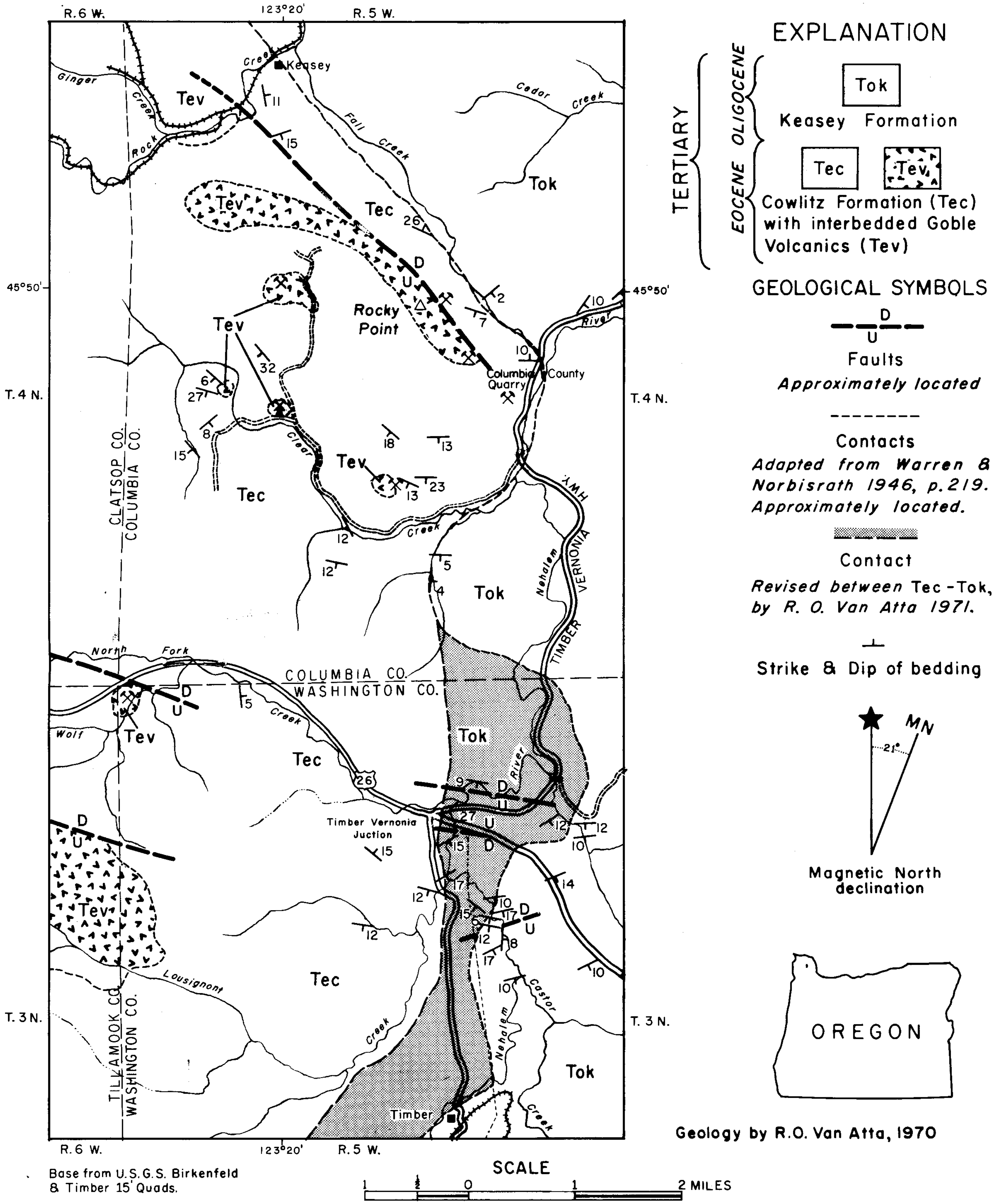


PLATE I. GEOLOGIC MAP OF PART OF THE UPPER NEHALEM RIVER BASIN, OREGON. STIPPLED AREA ORIGINALLY MAPPED AS COWLITZ FORMATION BY WARREN AND NORBISRATH (1946) CONSIDERED PART OF KEASEY FORMATION BY VAN ATTA (1971).

zone in the uppermost part of the sill and in the base of the conglomerate, seem to militate against the basalt being flow rock.

Basaltic dikes are exposed in several large quarries and in road cuts along the ridge crest at Rocky Point. At one quarry, hydrothermal mineralization of the basalt and overlying sediments shows the basalt is intrusive. Collapsed vesicles, originally lined with brown (palagonitic ?) glass, which appear as stringers up to 1 cm in length, are oriented nearly vertically. Arkosic siltstone and sandstone assigned to the sandstone member of the Cowlitz Formation crop out in numerous road cuts not more than a tenth of a mile from the ridge crest.

Warren and Norbisrath (1946, p. 219) mapped the basalts at Rocky Point as an uptilted block of the Tillamook Volcanic Series. Although a fault probably parallels the ridge on the northeast flank, as suggested by the presence of much steeper slopes there as compared to the gentle slope of the southwest flank, the intrusive nature of the basalt into the sandstone member of the Cowlitz Formation would make it more reasonable to include the basalt in the Goble Volcanics member of the Cowlitz Formation.

Basalt flows of the Goble Volcanics member are found on Rock Creek, 0.5 mile southwest of Keasey, Oregon, at the west end of a destroyed railroad trestle, interbedded with silicified greenish-gray muddy, volcanic sandstone and gray siltstone. The sedimentary interbeds are reddened and baked at their upper contacts with each of at least three lava flows. Other than this occurrence, no other flows of the Goble Volcanics member were found by this writer interbedded with the sandstone member of the Cowlitz Formation. Interbedded flows of the Goble Volcanics seem more common in the siltstone member of the Cowlitz, whereas intrusives of Goble Volcanics are more common in the sandstone member.

Keasey Formation, lower member

The Cowlitz Formation is overlain by beds of tuffaceous siltstone and mudstone which are assigned to the Keasey Formation. The type section of the Keasey Formation along Rock Creek, from the site of Keasey to a point downstream about 2 miles, was described by Schenck (1927, p. 457-458). Weaver (1937, p. 171-172) regarded the Keasey Formation as early Oligocene in age. Warren and Norbisrath (1946, p. 226) made the division between the Keasey Formation and the underlying Cowlitz Formation in the upper Nehalem River basin on the basis of mega- and microfaunal evidence. They described their upper shale member of the Cowlitz Formation (1946, p. 224) as "marine fossiliferous dark gray shale and fine-grained micaceous shaly sandstones, which contain increasing amounts of interbedded tuffaceous sandstone and water-laid tuff in the upper part." No typical section is specified nor is any thickness given for the unit.

Figure 6. Basalt pillows with included laminated mudstone. (Same locality as Figure 4)

Figure 7. Boulders in conglomerate overlying basaltic sill (lower right corner), related to Goble Volcanics. (Columbia County quarry)

Warren and Norbisrath (1946) proposed division of the Keasey Formation into "a lower dark shale member (type Keasey.....); a uniform middle member of massive silty tuffaceous shale with cemented beds; and an upper member of stratified tuffaceous sandy shales." These workers acknowledged the difficulty of distinguishing lithologically the beds they considered to be their upper shale member of the Cowlitz Formation from those they described as belonging to their lower member of the Keasey Formation.

One of the most complete sections of sedimentary beds which Warren and Norbisrath (1946) mapped as upper Cowlitz shale and lower Keasey shale is exposed along the Nehalem River, south of the Sunset Highway bridge near the Timber-Vernonia junction. Here, at least 1,115 feet of mudstone, siltstone, and minor fine-grained calcareous silty sandstones, with a few beds of calcareous pebbly sandstone can be traced for about $1\frac{1}{2}$ miles. A measured stratigraphic section of these beds is presented by Van Atta (1971).

The beds in this mudstone-siltstone sequence strike generally east-west to northeast, with local variations ranging from 62°NW to 60°NE, and dip 10° to 16°S. The individual mudstone beds are massive and range from 10 to 40 feet in thickness. Between them, in interbedded sequences of from three to ten beds, are thin layers of dark-gray to green-gray calcareous siltstone, dark-green calcareous pebbly volcanic sandstone, and dark-gray mudstone 0.5 to 2.0 feet thick. The beds of calcareous siltstone and sandstone are more resistant than the mudstone beds and they control the course of the Nehalem River wherever large meanders have developed.

Primary sedimentary structures other than graded bedding are rare in the mudstone, siltstone, and pebbly sandstone of the lower part of the Nehalem River section. Toward the upper part of the section well-laminated siltstone interbedded with thick massive mudstone becomes increasingly common. Calcareous pebbly volcanic sandstone interbeds are much rarer in the upper part of the section than in the lower.

A similar sequence of mudstone and siltstone with interbedded calcareous pebbly volcanic sandstone is exposed along the lower reaches of Lousignont Creek, a tributary of the Nehalem River from the west, and along the lower reaches of Robinson Creek, a tributary of the Nehalem River from the east. Along the Sunset Highway exposures of mudstone and siltstone seem to be similar in lithology to the Nehalem River section, although advanced weathering, slumping, and thick vegetation make observation difficult.

It is the conclusions of this writer that on the basis of lithology the mudstone and siltstone beds overlying the sandstone member of the Cowlitz Formation and exposed to the east of the Nehalem River should be placed in the lower member of the Keasey Formation because of their distinctive lithology as contrasted to that of the sandstone of the Cowlitz. This is in harmony with Article 6 of the Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature 1961, p. 650).

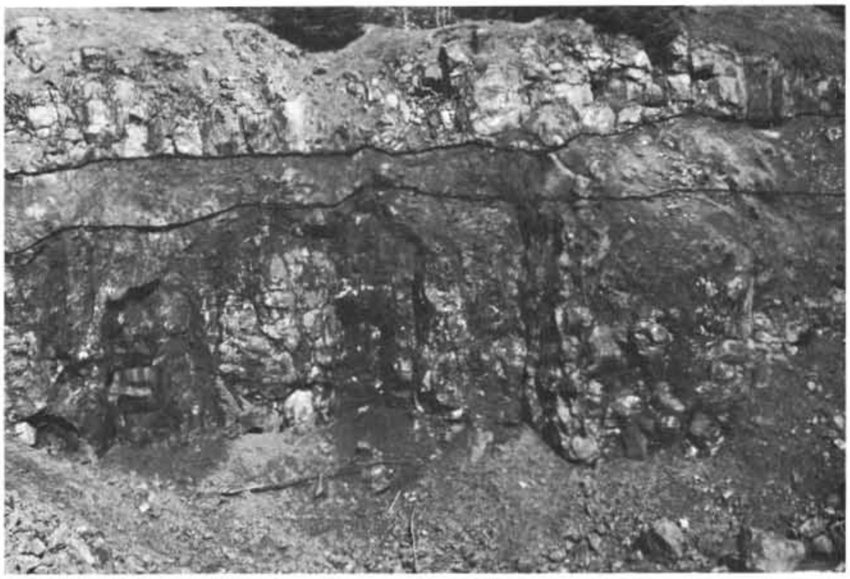


Figure 8. Conglomerate sliver included in basaltic sill. (Same locality as Figure 7)

In addition to the lithologic dissimilarities between the sandstone member of the Cowlitz Formation and the overlying mudstone, the apparent discordance between the two units suggests a possible unconformity as discussed above (see sandstone member).

Conclusion

Careful study of the petrology and stratigraphic relationships of the sedimentary and volcanic rocks west of the Nehalem River in the upper Nehalem River basin shows that the Cowlitz Formation there can be divided into a siltstone member and a sandstone member. The siltstone member is interbedded with volcanic rocks which constitute the Goble Volcanics member of the Cowlitz Formation. Locally, conglomerate is associated with the Goble Volcanics and the siltstone members, having been derived from the volcanics. The Goble Volcanics member is more commonly present as intrusive bodies in the sandstone member of the Cowlitz Formation.

The lithology and stratigraphic relationships of these rocks fully justify the use of the name Cowlitz Formation in the area of this study.

Beds of mudstone and siltstone which overlie the siltstone and sandstone of the Cowlitz Formation and which have been formerly considered to be an upper member of the Cowlitz Formation on the basis of faunal evidence, are lithologically indistinguishable from the lower member of the Keasey Formation. Therefore, these mudstones and siltstones should be included in the lower member of the Keasey Formation and the name Cowlitz should be applied only to the underlying sandstone, siltstone and intercalated volcanic rocks west of the Nehalem River.

Problems similar to those surrounding the contact between the Cowlitz and the Keasey Formations are found in a number of other parts of the Tertiary section of the Coast Range of Oregon. For example, the distinction between the Yamhill Formation and the upper part of the Tyee Formation is based largely on age. Likewise, shales of the Yamhill and Nestucca Formations are distinguished on the basis of age. An effort should be made to revise those contacts between formations which have been previously established on the basis of faunal distinctions so that they may better conform to the lithologic standards for definition of a formation as presented in the Stratigraphic Code.

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Bibliography

American Commission on Stratigraphic Nomenclature, 1961, Code of Stratigraphic Nomenclature: Bull. A.A.P.G., vol. 45, p. 645-665.

Baldwin, E. M., 1964, Geology of Oregon, 2nd edition: Edwards Brothers, Ann Arbor, Mich., 165 p.

Bouma, A. H., 1969, Methods of study of sedimentary structures: Elsevier Publ. Co., 458 p.

Deacon, R. J., 1953, A revision of upper Eocene and lower Oligocene stratigraphy in the upper Nehalem River basin, northwest Oregon: Unpub. Master's thesis, Oregon State University, Corvallis, Oregon 84 p.

Folk, R. L., 1968, Petrology of sedimentary rocks: Hemphills, Drawer M., University Station, Austin, Texas, 170 p.

Henrikson, Donald A., 1956, Eocene stratigraphy of the lower Cowlitz River-Eastern Willapa Hills area, S.W. Washington: Wash. Div. of Mines and Geol. Bull. 43

Pettijohn, F. J., 1957, Sedimentary rocks, 2nd ed.: Harper's Book Co.

Schenck, H. G., 1927, Marine Oligocene of Oregon: Univ. of Calif., Dept. of Geol. Sciences Bull., vol. 18, no. 12, p. 449-460.

Twenhofel, W. H., 1937, Terminology of the fine-grained mechanical sediments: Rept. Comm. on Sedimentation for 1936-1937, National Research Council.

Van Atta, Robert O., 1971, Sedimentary petrology of some Tertiary Formations, upper Nehalem River basin, northwest Oregon: unpublished Ph.D. dissertation, Oregon State University, 229 p.

Warren, W. C., Hans Norbisrath and Rex Grivetti, 1945, Geology of northwest Oregon, west of the Willamette River and north of latitude 45° 15': U.S. Geol. Survey Oil and Gas Inv., Preliminary Map 42.

________ and Hans Norbisrath, 1946, Stratigraphy of upper Nehalem River Basin, N.W. Oregon: Am. Assoc. Pet. Geol. Bull., vol. 30, no. 2, p. 213-237.

Weaver, C. E., 1937, Tertiary stratigraphy of western Washington and northwestern Oregon: Washington Univ. Publ. in Geol., vol. 4.

Williams, H., F. J. Turner and C. M. Gilbert, 1954, Petrography: An introduction to the study of rocks in thin section: W. H. Freeman and Co., San Francisco, 406 p.

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NEW MINERALS YEARBOOK AVAILABLE

The U.S. Bureau of Mines Minerals Yearbook for 1969 is for sale by the U.S. Government Printing Office, Washington, D.C. 20402. Vol.s 1-2 (combined) "Metals, Minerals and Fuels," is $6.00; vol. 3 "Area Reports: Domestic," is $4.75; and vol. 4, "Area Reports International," is $4.75.

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* * * * *

GREEN DIAMOND ABRASIVES

A relatively new and expanding industry in Douglas County that utilizes a waste product from the Hanna Nickel Smelter is a good example of mineral conservation practice. The Mining-Minerals Manufacturing Co. of Riddle, Oregon produces a low-cost, high-quality sandblasting grit, roofing granules, and other specialty sands from granulated smelter slag purchased from Hanna. From a modest beginning in 1961 with three employees, the plant (Figure 1) has grown to a 10-employee operation producing approximately 3000 tons per month.

Sandblasting grit in a variety of sizes that comply with government and industry specifications is the major product. It is marketed in bulk and bags in California and the Pacific Northwest under the name of "Green Diamond Abrasives" (Figure 2). Minor amounts of grit have been sold for use in non-skid coatings and road sanding material. Roofing granules, the next most important product, are marketed in bulk in the Pacific Northwest, mainly in Portland.

During the smelting and refining of ore from Nickel Mountain, the Hanna Smelter generates large quantities of slag which must be disposed of. For ease of handling, the slag is fragmented. Jets of high-pressure water quench the molten material and explosively break it into gray-green spheres, sharp irregular shards, and grains as it is poured into granulation bins near the smelter. The granular material is then conveyed to the ever-growing multi-million ton slag pile that now constitutes an almost inexhaustable source of raw material for the Mining-Minerals Manufacturing Co.

The Green Diamond plant is located about 3½ miles east of the Hanna Smelter along the same spur of the Southern Pacific Railroad. The raw, gray-green granulated slag arrives in bottom-dump rail cars; after coarse screening it is dried and sized, and most is conveyed to appropriate storage tanks for bulk loading or bagging as abrasives. Another circuit of the flow sheet includes crushing and additional sizing for production of roofing granules and other specialty products.

The recent addition of more efficient dust collecting devices insures operation within the minimum standards for air pollution set by the Oregon Department of Environmental Quality.

Chemically the slag is a glass composed of silica (51 percent), magnesium oxide (23 percent), and iron oxide (23 percent). Chromic oxide and aluminum oxide average about 1 percent each. Other elements present occur in only trace amounts.

The slag appears to be quite durable both mechanically and chemically. There is little or no chemical alteration on exposure to weather. It is also known to possess good refractory properties. Continued research into potential new uses of this growing by-product resource should result in expanded markets and increased production.

Figure 1. A general view of the "Green Diamond" plant at Riddle, Oregon 1971. The large storage tanks with their associated conveyors are the bulk loading facility; rotary dryer and screening circuits are behind the storage tanks. The bagging facility is at the left. Piles of granulated slag in the foreground.

Figure 2. Sandblasting grit in a variety of sizes is marketed as "Green Diamond" in 100 lb. bags.

EASTERN OREGON EARTHQUAKES OF JULY 13-14, 1971

by Lawrence H. Jaksha
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A mild series of earthquakes took place near the Thief Valley Reservoir on the Powder River in northeastern Oregon on July 13 and 14 of 1971. The locations as determined by National Oceanic and Atmospheric Administration (NOAA) indicates that these events are a continuation of the tectonic readjustment discussed by Couch and Whitsett in 1969.*

The largest earthquake in the series was observed at six seismograph stations. These stations and their associated P phase arrival times are listed below. The three aftershocks were observed only at the Blue Mountains Observatory (BMO).

Station	Location	Arrival Time (GMT)
BMO	Baker Oregon	23h 29m 34.2s
HAN	Hanford, Washington	23h 29m 58.2s
HHM	Hungry Horse, Montana	23h 30m 33.3s
LDM	Libby Dam, Montana	23h 30m 25.8s
LON	Longmire, Washington	23h 30m 16.9s
NEW	Newport, Washington	23h 30m 17.4s

The geographic coordinates of the largest earthquake are 44.8 N latitude, 117.9 W longitude. The epicenter is located approximately 10 km WSW of the Thief Valley Reservoir. The origin time of the event is calculated to be 23h 29m 25.2s GMT on July 13, 1971. The solution of the earthquake suffers somewhat from poor azimuth but the inference of association with the event discussed by Couch and Whitsett is justified.

The P wave arrival times and magnitudes of the series as observed at BMO are as follows:

Date	Time GMT	Magnitude
July 13, 1971	23h 29m	3.0
July 13, 1971	23h 33m	2.0
July 13, 1971	23h 35m	Very Small
July 14, 1971	04h 13m	2.2

The magnitudes given refer to the Richter Scale and were derived from the recorded ground motion at BMO.

Several residents in the sparsely populated country between North Powder and Haines report having both felt and heard this latest quake, and some who experienced the 1969 event felt that this one was the stronger and longer lasting of the two. No damage attributable to the recent quake was reported.

* The North Powder Earthquake of August 14, 1969, by R. Couch and R. Whitsett. The ORE BIN, vol. 31, no. 12, December 1969.

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