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Released May 6, 2002:

Earthquake hazard maps and seismic risk assessment for Klamath County, Oregon, by Zhenming Wang and Yumei Wang, Oregon Department of Geology and Mineral Industries. Interpretive Map Series map IMS-20; 1 CD, \$10.

IMS-20 is the latest in a series of relative earthquake maps and studies by the Oregon Department of Geology and Mineral Industries. In November 2000, the Department released IMS-19, Relative Earthquake Hazard Map of the Klamath Falls Metropolitan Area.

The 1993 Klamath Falls earthquakes (magnitudes 5.9 and 6.0) caused damage to more than 1,000 buildings and \$10 million in losses. Although we do not

know when the next damaging earthquake will occur, we can, with this study, assess the potential earthquake hazards as well as the potential damages and losses.

With support from the Federal Emergency Management Agency (FEMA) and Oregon Emergency Management (OEM), and with help from the Oregon Institute of Technology and Klamath County Emergency Services, these new earthquake hazard maps and the seismic assessment were developed on the basis of HAZUS99 software. HAZUS99 is a seismic-risk-assessment software developed by FEMA and the National Institute of Building Sciences (NIBS). The information from the seismic-risk assessment will help local governments, land use planners, and emergency managers prioritize areas for risk mitigation in Klamath County.

Two of the four scenarios modeled in this study include (1) a scenario earthquake of magnitude 6.0, located at the Klamath Falls city center, which according to the HAZUS99 modeling would cause damage to about 10,000 buildings, losses of about \$246 million, and about 50 injuries and deaths; and (2) a scenario earthquake of magnitude 6.5, also located at the Klamath Falls city center, which according to the HAZUS99 modeling would cause damage to about 13,000 buildings, losses of about \$387 million, and more than 100 injuries and deaths.

Continued on page 34, DOGAMI Publications

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Cover photo

Steens Mountain, Harney County, is one of the fault blocks created by the extensional tectonic processes that occurred during the last 10 million years and have given the Oregon part of the Basin and Range Province its characteristic horst-and-graben (fault block and depression) topography.

Miocene volcanism and Pleistocene glaciation have carved up Steens Mountain more than the other scarps in southeastern Oregon.

View is to the southeast from the Steens Mountain Loop road toward the Alvord Desert. Photo contributed by Oregon Geology reader Steve Fritz of Portland.

The Triassic/Jurassic System boundary in the John Day Inlier, east-central Oregon

by David G. Taylor, 5004 SW Lowell; Portland, Oregon 97221, e-mail Blitz124@attbi.com.; and Jean Guex, Institut de Géologie et Paléontologie, BFSH2, CH-1015, Lausanne, Switzerland., e-mail Jean.Guex@igp.unil.ch

ABSTRACT

Rail Cabin Argillite and overlying Graylock Formation are uppermost Triassic and lowermost Jurassic marine rock units in the Suplee-Izee area in eastern Oregon and provide a record of the Triassic/Jurassic System boundary.

At the type locality for the Rail Cabin Argillite (Morgan Mountain), the system boundary beds occur at the top of the formation, are approximately 60 m thick, and lack macrofossils. Just below that interval, the formation yields Late Triassic fossils assigned to the Columbianus Zone. Above, in the Graylock Formation, are found Early Jurassic (late Hettangian) fossils belonging to the Morganense Zone. At a second locality (Camp Faraway), a reworked block in the Graylock Formation reveals the first Rhaetian fossils from Oregon: *Arcestes* cf. *gigantogaleatus* and an indeterminate ostreid shell fragment. The sequence is compared to a Nevada section in the Gabbs Valley Range, which may serve as the standard of reference for the system boundary. New species described include the bivalves *Agerchlamys boellingi* and *Kalentera* (?) *lawsi* and the ammonites *Sagenites striata*, *S. minaensis*, *Choristoceras shoshonensis*, *C. robustum*, *Vandaites newyorkensis*, *Cycloceltites tozeri*, and *Gabboceras delicatum*. *Gabboceras* is a new genus. New biochronologic units include the Striata and Minaensis subzones and the Newyorkensis and Rhaeticum zones.

INTRODUCTION

The Triassic/Jurassic System boundary marks one of the five most pronounced extinction events that occurred in the last 250 million years and involved wholesale turnover of

both marine and terrestrial organisms. Among the marine organisms, the conodonts became extinct, and the ammonites nearly met their demise, while the nautilids, brachiopods, bivalves, corals, radiolaria, and a host of other groups were decimated.

This paper describes latest Triassic and earliest Jurassic sections in the Izee district of the Ochoco Mountains, east-central Oregon (Figure 1B). The boundary beds are at the top of the Rail Cabin Argillite, and fossiliferous Early Jurassic faunas occur in the overlying Jurassic Graylock Formation. The Rail Cabin Argillite has been known to furnish late Norian macrofossils (Dickinson and Vigrass 1965), while the Graylock Formation yields ammonites of late Hettangian and possibly earliest Sinemurian age (Taylor 1988, 1998a). Although lack of fossils inhibits determination of the age of the rocks very close to the boundary, description of the sequence is important for comparison with sections of the same age elsewhere. The most complete marine sections spanning the boundary are in Great Britain, Austria, Chile, Peru, Russia, British Columbia, and Mexico (Sonora) and in the United States in Nevada (see Guex and others, 1997, for discussion and further references). North America has few localities that preserve the transition; the Oregon sequence, therefore, provides an important reference section to help characterize the nature of the boundary in North America.

Close comparison is made with the Nevada section (Figure 1A), which preserves an exceptional sequence revealing latest Triassic and earliest Jurassic ammonites, bivalves, nautilids, and other organisms in stratigraphic succession (Taylor and others 1998b, 2000). Any boundary

section will need to be compared to the one in Nevada because of its comparatively complete faunal record spanning the boundary. For that reason, the Nevada section has been proposed as the stratotype for the System boundary (Taylor and others 1983, Guex and others 1997). A few characteristic new species along with description of the faunal sequence are given for the Nevada section to help establish a zonation (=time scale) for the latest Triassic in North America (Figure 2) and to provide comparison with the Oregon section.

STRATIGRAPHY

The Rail Cabin Argillite and the Graylock Formation in the Ochoco Mountains consist of several hundred meters of mud-grade siliciclastic and minor carbonate rocks. Both formations were described in Dickinson and Vigrass (1965).

The Rail Cabin Argillite is composed of siliceous, dark-gray mudstone with minor intercalations of limestone and zeolitized tuff. The mudstone is laminated in part. The formation is about 300 m thick in the vicinity of its type area at Morgan Mountain (Figure 1B, locality 2; Figure 3) (Dickinson and Vigrass, 1965); it is roughly half that thickness at Hole-in-the-Ground (Figure 1B, locality 3; Figure 4). Only the top of the formation is exposed at Camp Faraway (Figure 1B, locality 1; Figure 5).

The Graylock Formation is composed of up to 120 m of thin- to medium-bedded mudstone, siltstone, and limestone. It has a lower member composed of calcilutite and mudstone and an upper member of mudstone and siltstone. In the type area and at Hole-in-the-Ground, the

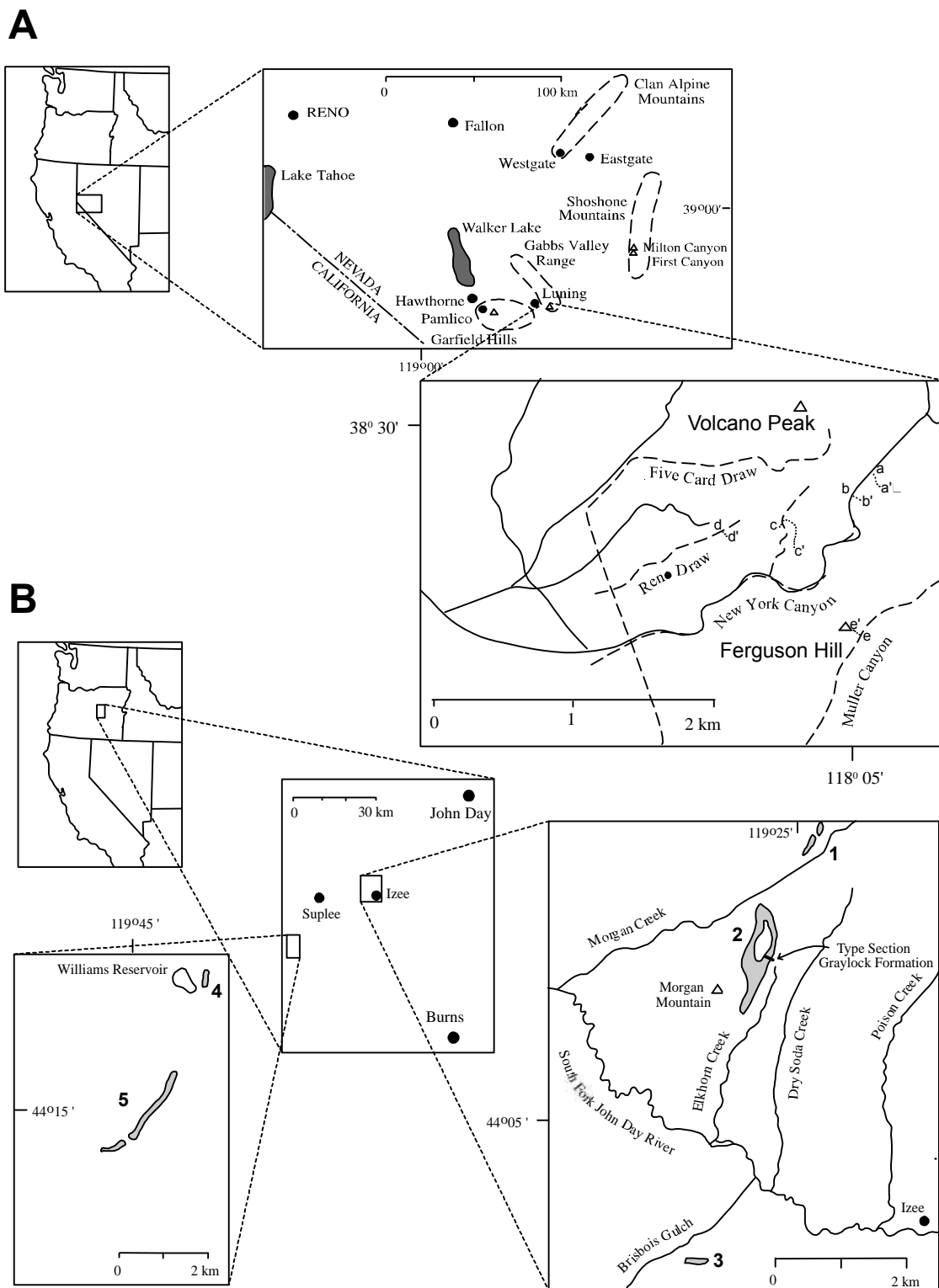


Figure 1. Sketch maps showing fossil localities in Nevada (A) and Oregon (B). Nevada areas enclosed in dashed lines represent mountain ranges in which localities occur. Enlargement of Gabbs Valley Range portion known as New York Canyon area shows roads (solid lines), significant drainages (dashed lines), and stratigraphic sections (dotted lines) described in Figures 7, 9, and 10; primed letters for stratigraphic sections (labeled a through e) indicate top of section. Oregon localities are marked as shaded areas in enlarged maps and include those at (1) Camp Faraway, (2) Morgan Mountain, (3) Hole-in-the-Ground, (4) Williams Reservoir, and (5) exposures south of Williams Reservoir. Solid lines indicate streams.

System	Stage	WESTERN CORDILLERA		EUROPE	
		Zone	Subzone/Horizon	Zone	Subzone
Jurassic	Hettangian	Canadensis (partial) (19)		Angulata	Depressa
		Oregonensis (18)			Complanata
		Morganense (17)			Extranodosa
		Sunrisense (16)		Liasicus	Laqueus
		Pleuroacanthitoides (15)			Portlocki
		Coronoides (14)		Planorbis	Johnstoni
		Occidentalis (13)			Planorbis
		Mulleri (12)		?	?
		Polymorphum (11)			
		Pacificum (10)			
Triassic	Rhaetian	Minutum (9)			
		Spelae (8)			
		Crickmayi (7)		Marshi	Marshi
		Rhaeticum (6)			Ammonitifforme
			Tozeri Horizon (5)	Stuerzenbaumi	Stuerzenbaumi
		Newyorkensis (4)			Haueri
		?		Suessi	
		Amoenum (3)	Minaensis Subzone(3b)		
			Striata Subzone (3a)		
		Cordilleranus (2)			
Norian		Columbianus (1)	(4 subzones)	Macer	
				Hogarti	

Figure 2. Correlation of uppermost Triassic and earliest Jurassic zones.

formation conformably overlies the Rail Cabin Argillite. In the former area, the contact between the two formations is transitional over a few meters, while in the latter the contact is sharper and more readily delineated. The Graylock Formation is unconformably overlain by the Mowich Group.

Dickinson and Vigrass (1965) found the Graylock Formation and the Rail Cabin Argillite to be limited in areal extent north and northwest of Izee. One author (D. Taylor) subsequently discovered additional exposures of the formations at Hole-in-the-Ground (mentioned in Blome, 1984) and recognized the presence of the Graylock Formation in the Grindstone terrane.

One locality, at Williams Reservoir (Figure 1B, locality 4; Figure 6) was originally allocated to unnamed "Hettangian" beds by Buddenhagen

(1967) who based his determinations on ammonite identifications by R.W. Imlay. These additional exposures reveal that the formations have wider distributions than known originally.

The Volcano Peak Group in the Gabbs Valley Range in Nevada spans the system boundary and includes the Upper Triassic Gabbs and Lower Jurassic Sunrise Formations (Figure 7). The formations are composed of alternating mudstone/siltstone and limestone units (Muller and Ferguson, 1936, 1939; Taylor and others, 1983). The Nevada sediments differ from the corresponding units in Oregon in that they have less volcanogenic material and were deposited in a back-arc basin (Taylor and Smith, 1992) rather than in an intra-arc setting (Dickinson and Thayer 1978, Smith and Taylor, 1992).

BIOCHRONOLOGY

The biochronology (=time scale based on fossil organisms) for the Western Cordillera is given in Figure 2. The faunal sequence includes new Triassic zones and subzones from Nevada, which permit detailed correlation between the North American sections as well as those elsewhere (Figure 8).

Triassic

The Triassic part of the succession dealt with here begins in the late Norian with a fauna from the upper part of the Rail Cabin Argillite (Figure 3) at Morgan Mountain (Dickinson and Vigrass, 1965). The joint occurrence at this level of *Neohimavatites*, *Alloclionites*, *Pseudosirenites*, *Leislingites*, *Arcestes*, and *Placites* indicates an assignment to the later part of the Columbianus Zone (subzone 3 of Tozer, 1994). Another locality at Hole-in-the-Ground (Figure 4) does not have any ammonoids but yields the clam *Monotis subcircularis*. This species provides a younger age assignment, to the Cordilleranus Zone. The remainder of the Triassic includes the Amoenum, Newyorkensis (*nov.*), Rhaeticum (*nov.*), and Crickmayi Zones, two new subzones (Striata and Minaensis) and a new horizon (Tozeri), which are well represented in the Gabbs Formation and described below. None of these correlate with the Alpine European Haueri Subzone (Krsytyn 1987, 1990), and that interval is likely represented by a depositional hiatus at the contact between the Nun Mine and Mount Hyatt Members.

The **Amoenum Zone** (Index species: *Cochloceras amoenum*) was first described by Tozer (1979), who designated its type locality in the Pardonet Formation, British Columbia. Two new subzones can now be recognized on the basis of the material from the Gabbs Formation (Figure 7). One is the Striata Subzone (Index species: *Sagenites striata*) from the lower part of the Nun

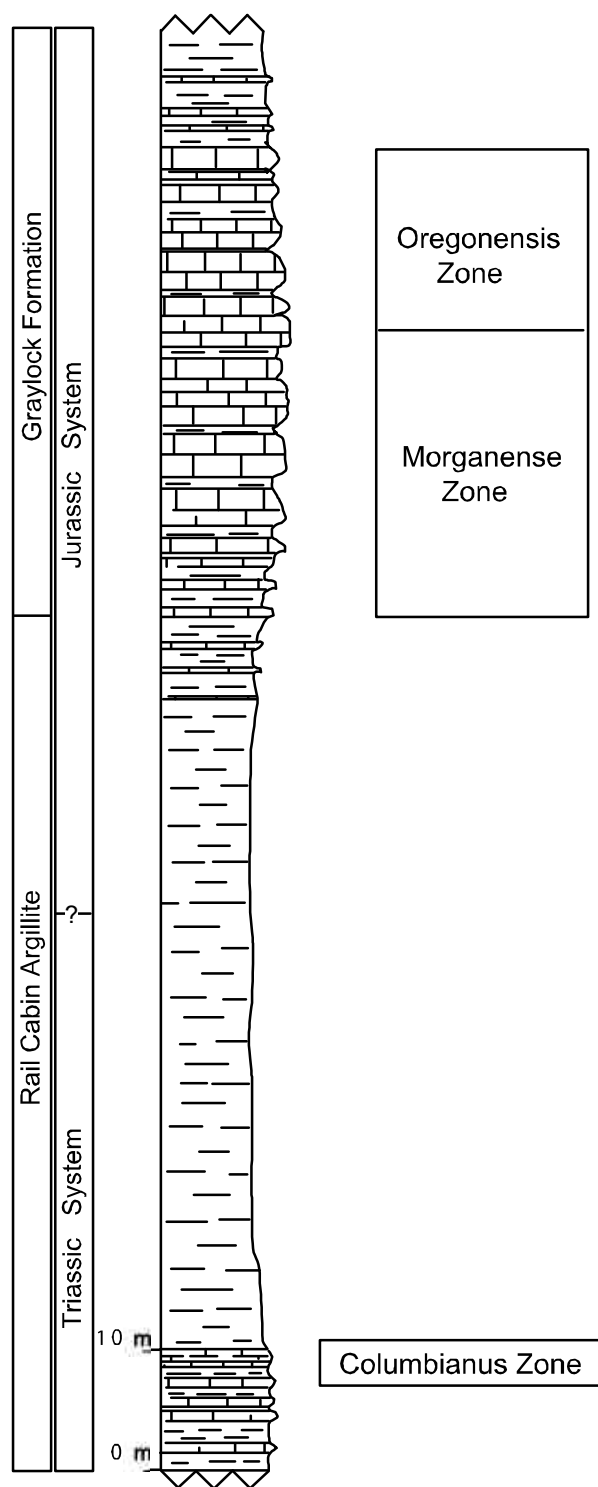


Figure 3. Stratigraphic section at Morgan Mountain.

Mine Member, while the other is the Minaensis Subzone (Index species: *Sagenites minaensis*) from the upper part of the same member.

The **Striata Subzone** is characterized by the restricted occurrence of the name-bearer and *Peripleurites*

aff. *roemeri*, *Stenarcestes ptychodes* (Mojsisovics) is also known from one specimen. The type locality for the subzone is the lower 35 m of measured section in the Nun Mine Member (Figure 7; Figure 1A, stratigraphic section c-c').

The **Minaensis Subzone** is recognized by the name bearer and *Cochloceras* aff. *canaliculatum* (Hauer), and the type locality is in the upper 47 m of the Nun Mine Member (Figure 7; Figure 1A, stratigraphic section c-c'). The Minaensis Subzone also occurs in Sonora, Mexico, where author Taylor found specimens of *Sagenites minaensis* along with *Arcestes nevadanus* in the upper part of unit 2 of the Antimonio Formation (Gonzales-Leon and others, 1996). The Amoenum Zone correlates with the Reticulatus Zone of Alpine Europe.

The **Newyorkensis Zone** (index species: *Vandaites newyorkensis*) is restricted to the basal 5 m of the Mount Hyatt Member. Type locality for the zone is at stratigraphic section c-c' (Figure 1A; Figure 7). The zone yields the name bearer and several associated species. The zone correlates best with the Stuerzenbaumi Subzone from Austria. Krystyn's (1990) identification of *V. stuerzenbaumi* from the New York Canyon area should be amended to the new species, *V. newyorkensis*.

The superjacent unit is the **Tozeri Horizon**. It is represented by common *Cycloceltites tozeri* along with *Placites*, *Arcestes*, and *Rhacophyllites*. The type locality for the Tozeri Horizon is at stratigraphic section c-c' (Figure 1A). There, the typical fauna is represented from 12.5 to 14 m above the base of the Mount Hyatt Member (Figure 7). The horizon may correlate with the basal part of the European Marshi Zone, as it probably yields fragmentary material referable to *Choristoceras*.

The **Rhaeticum Zone** occurs next in the sequence and is typically represented in the upper part of the Mount Hyatt Member at the type Gabbs Formation (Figure 1A, stratigraphic section c-c') from 24 to 37 m above the base of the member (Figure 7). *Choristoceras rhaeticum* is locally common along with *Arcestes nevadanus* Gabb and occasional *Placites*. The zone correlates with the alpine Ammonitiforme Subzone (Krystyn 1987).

The youngest fauna of Triassic age is the **Crickmayi Zone** (Figures 7, 9, and 10) described by Tozer (1979). He furnished a type locality in southern British Columbia in the Tyauhton Group. The zone in its type area is recognized by the presence of *Choristoceras crickmayi*. As employed in this paper, the zone does not extend materially below the range of that species. In Nevada, the zone occurs in the upper 5 m of the Mount Hyatt Member and the basal 1 m of the Muller Canyon Member (Figures 9 and 10). Distinctive ammonoids include *Choristoceras crickmayi*, *C. shoshonensis*, *C. marshi*, *C. robustum*, *Arcestes nevadanus*, *A. cf. gigantogaleatus*, *Rhacophyllites* aff. *debilis*, and *Placites*. The zone correlates with the Alpine European Marshi Sub-zone. The Crickmayi Zone has two horizons, a lower one with *C. marshi* and *C. robustum* just below the top of the Mount Hyatt Member and an upper one from the top bed of the Mount Hyatt to the base of the Muller Canyon Member. The latter furnishes *C. crickmayi* and *C. shoshonensis* (Figure 10).

Jurassic

The Western Cordillera comprises 12 zones of Hettangian age. These are described in Taylor (1988, 1998a), Guex (1995), and Taylor and others (2001) and are shown in the zonation chart (Figure 2).

THE SYSTEM BOUNDARY

The system boundary in the Izee area lies in the Rail Cabin Argillite. At Morgan Mountain, it occurs within about 60 m of section at the top of the formation (Figure 3). These beds are a monotonous sequence of partly laminated, weakly calcareous mudstone and siltstone; they lack macrofauna and are bounded below and above by fossiliferous limestone referable to the Triassic Columbianus Zone and Jurassic Morganense Zone, respectively. At Hole-in-the-Ground (Figure 4), the boundary lies within the mudstone sequence between the

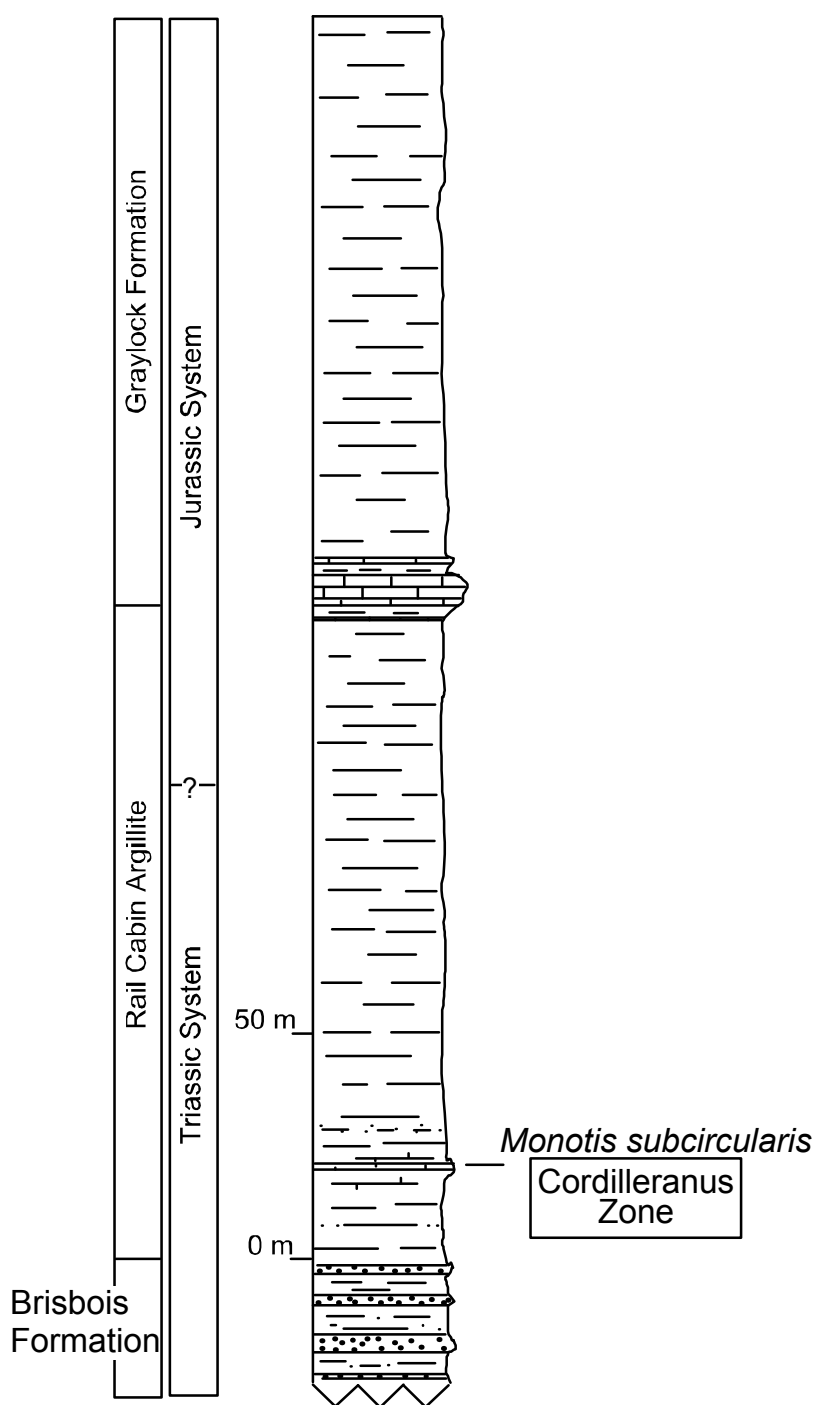


Figure 4. Stratigraphic section at Hole-in-the-Ground.

Cordilleranus Zone and the Graylock Formation. Fossiliferous beds of the latest Norian Stage through early to middle Hettangian age (earliest Jurassic) are missing at both localities.

Of special interest is a reworked sandy limestone block in the Jurassic Graylock Formation at Camp Faraway (Figure 1B, locality 1) from a calcareous sandstone bed. The block

yielded a specimen of *Arcestes* cf. *gigantogaleatus* and an ostreid (oyster) shell fragment. The block most likely was transported from the west or north, where local uplift and erosion unroofed nearby uppermost Triassic sediments. The occurrence suggests that a fossiliferous shallow-water facies of latest Triassic age existed nearby.

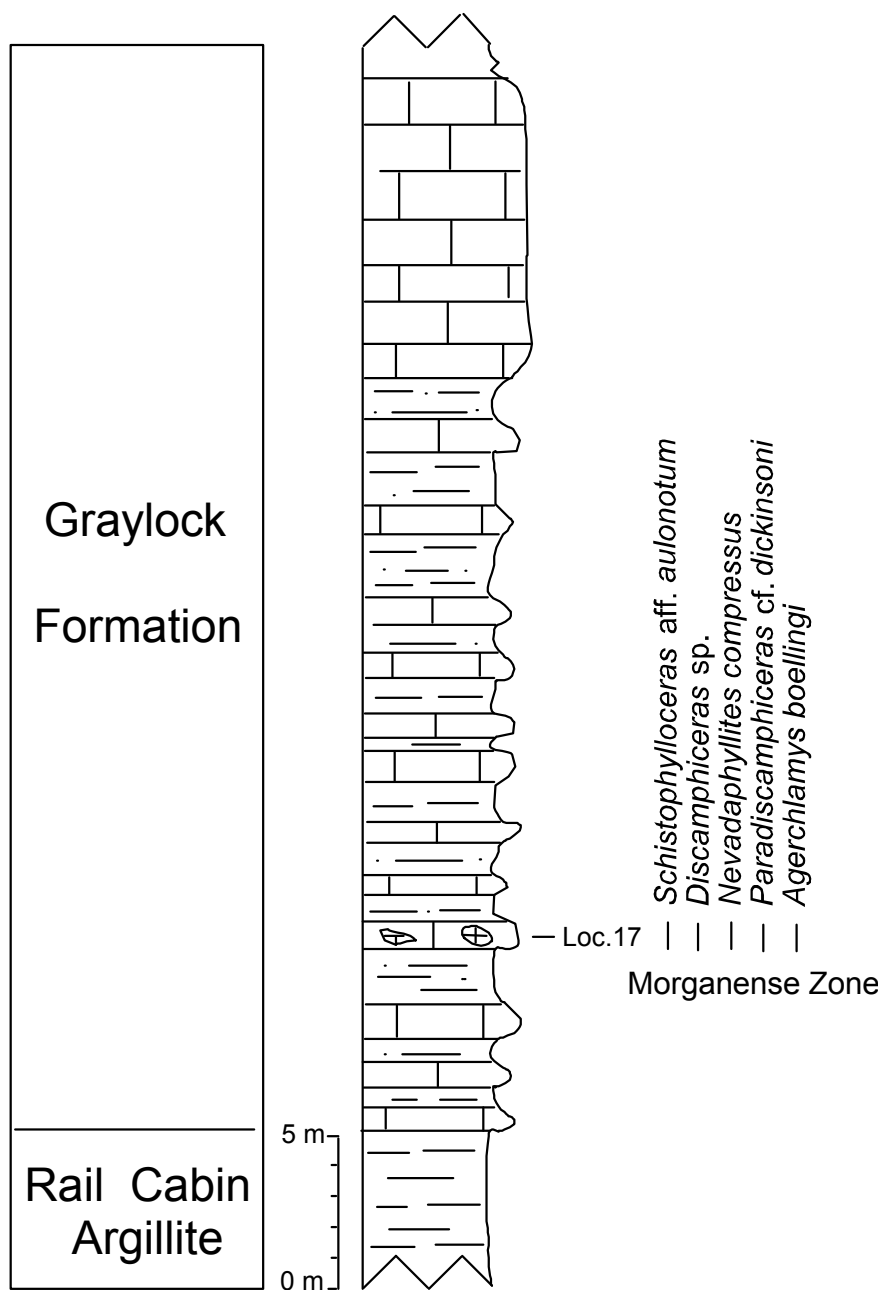


Figure 5. Stratigraphic section at Camp Faraway.

Faunal turnover in the Gabbs Formation is best documented in a reddish siltstone unit (Figures 9 and 10) comprising the lower part of the Muller Canyon Member (Taylor, 1998b; Taylor and others, 2000). This reddish siltstone unit yields *Choristoceras shoshonensis*, *C. crickmayi*, and *Arcestes nevadanus* (Gabb) in its basal 1 m and *Psiloceras tilmanni*, *Psiloceras spelae*, and *Juraphyllites* sp. near its top (Guex and others,

1998; Taylor, 1998b; Taylor and others, 2001). The basal beds of the upper division of the member yield a bivalve fauna with *Oxytoma inequivalvis*, *Kalentera* (?) *lawsi* n.sp., and *Agerchlamys boellingi* n.sp. Guex (1980; 1982; 1995, beds Z 1–4) described *Psiloceras* and *Choristoceras minutum* from the upper part of that division (Minutum Zone). We suggest placement of the system boundary within the reddish siltstone

in the lower part of the Muller Canyon Member, between the Crickmayi and Spelae Zones. That interval separates typically Triassic faunas below from those above which overall have Jurassic affinity.

A section in Sonora, Mexico (Gonzales and others, 1996), was originally interpreted as preserving a conformable boundary sequence in the Antimonio Formation. During a visit to the section, author Taylor excavated the still covered boundary beds and located a sharp contact at the base of a limestone member, which yields the late Hettangian ammonite *Sunrisites sunrisensis*. At the same time, Gonzales located *Choristoceras* cf. *nobile* just below the contact, which suggests an assignment of latest Triassic beds there to the Rhaeticum Zone. Consequently, the hiatus in Sonora includes the Crickmayi Zone and the lower and middle Hettangian (Figure 11). The sharp contact between the siltstone and limestone appears to be disconformable, although a fault can not be precluded, as the contact is heavily mineralized and the matrix fragmented.

The Queen Charlotte Islands preserve the other relatively complete boundary section in North America (Tipper and Guex, 1994; Tipper and others, 1994). There, the highest Triassic ammonite is *C. rhaeticum* (indicating a correlation with the Rhaeticum Zone), while early Hettangian ammonites occur some 30 m higher in the section (Figure 11).

COMPOSITE ASSEMBLAGES

The basinal settings varied for the North American sections spanning the system boundary. The Rail Cabin Argillite and the Graylock Formation as well as the relevant formations in the Queen Charlotte Islands are volcanoclastic units deposited in basins proximal to volcanic arcs. The Gabbs and Sunrise Formations were deposited in the southeastern margin of a back-arc basin, while the Antimonio Formation was laid down in a setting that was proximal to the cra-

ton. The sections in Nevada and Sonora differ from those in Oregon and British Columbia in having abundant shallow-water carbonate sediments. The section in Sonora is the only one having throughout quartzose sediments derived from the craton and abundant carbonized plant detritus.

A summary of composite assemblages for the localities is given to provide better understanding of the relative depths of sedimentation for these sections. A series of composite assemblages was described in Taylor (1982) and Taylor and others (1983) to establish a nearshore-offshore sequence based on the basal distribution of macroinvertebrate organisms. Six assemblages were recognized, termed Composite Assemblages A to D (C and D were subdivided, which resulted in a total of 6 assemblages). Assemblage A is the extreme shallow-water one, characterized by brachiopods and bivalves that may indicate intertidal to shallow subtidal environments. Ammonites are lacking. The next-lower Assemblage B is dominated by thick-shelled bivalves and few ammonites, while Assemblage C has common and diverse ammonoids as well as diverse bivalve communities. The outer part of Assemblage C, C(2), reveals the inshore occurrence of pectinacean bivalves such as *Posidonia*, *Meleagrinella*, *Monotis*, and inoceramids. Assemblage D reflects the joint occurrence of ammonites and thin-shelled pectinaceans offshore of diverse benthic bivalve associations. The outer part of this assemblage, D(2), excludes belemnites which thrived in shallower waters. The reader is referred to the two papers cited above for a full description of the assemblages.

A new composite assemblage is proposed here: Assemblage E, for the deeper parts of basins which are nearly devoid of macrofauna. There, ammonite and pectinacean occurrences are uncommon, while planktonic microorganisms such as radiolaria may be abundant. Where trace

fossils occur, they consist primarily of *Planolites*. The associated sediments are primarily mud-grade rocks which commonly have fine parallel lamina-

tions. This facies can often be regarded as having been deposited in an oxygen-deficient environment.

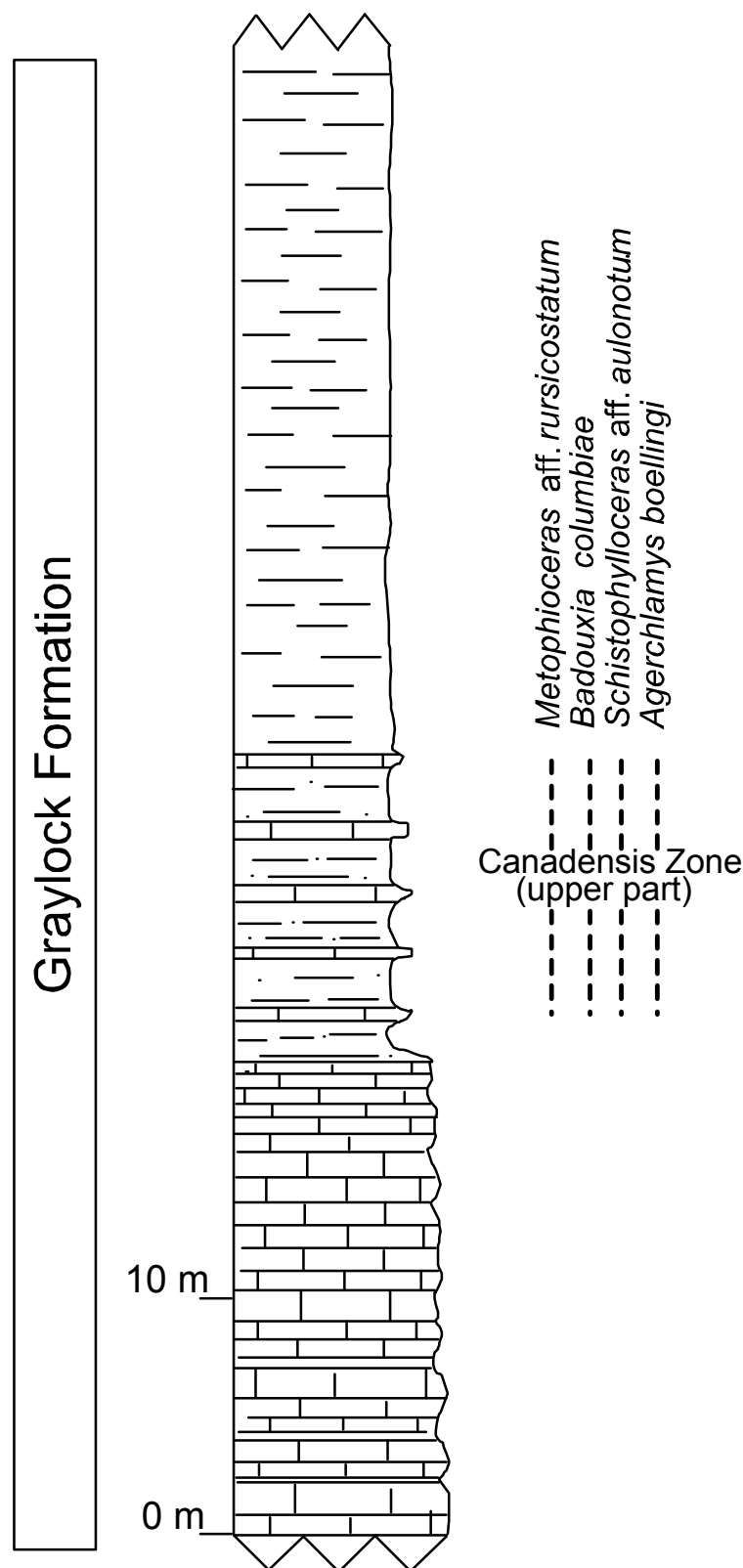
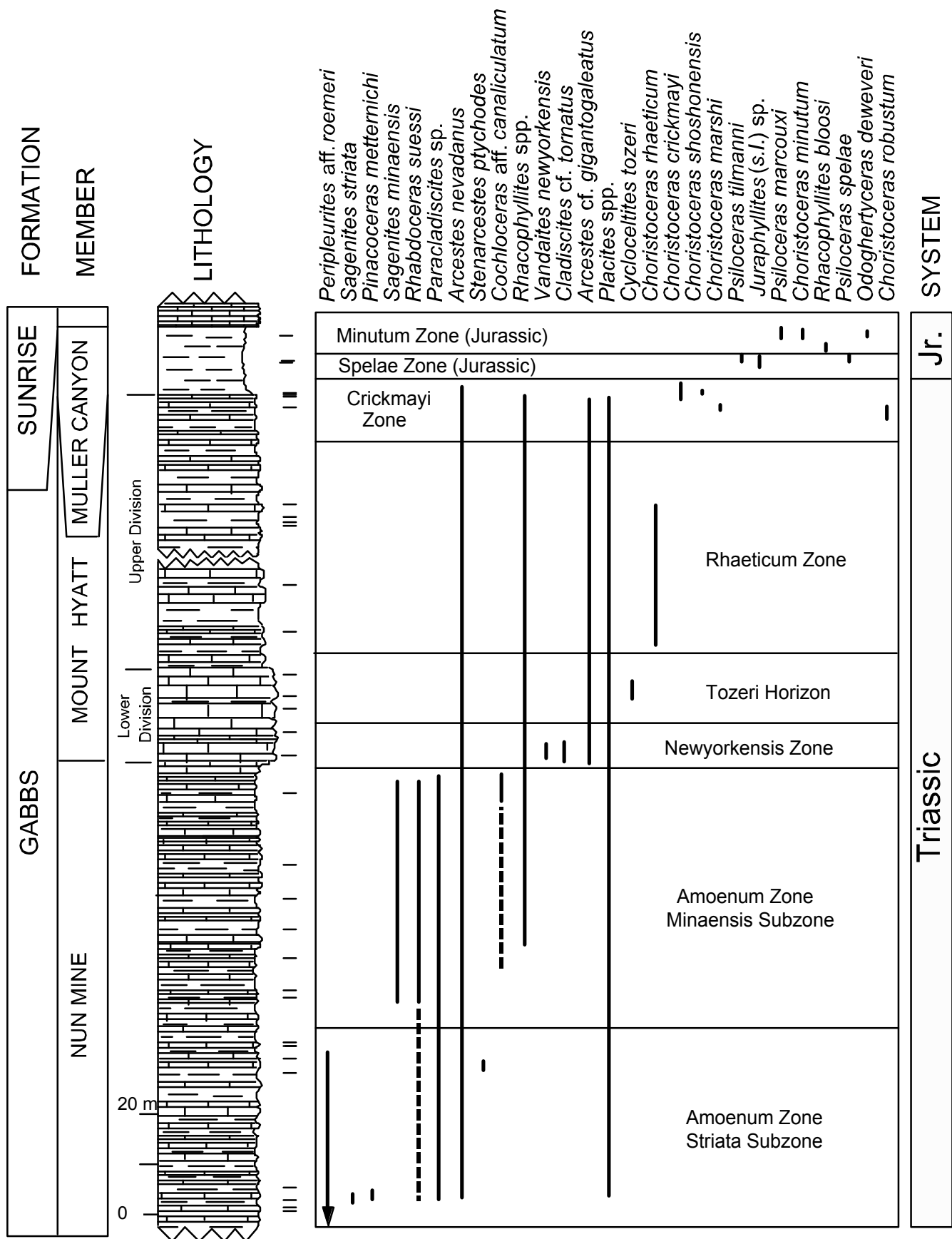


Figure 6. Stratigraphic section at Williams Reservoir.



	NE RUSSIA (Polubotko and Repin, 1983)	NEVADA (Guex and others, 1998; Taylor and others, 2000; this report)	ANDES (Hillebrandt, 2000)	BRITISH COLUMBIA Queen Charlotte Is. (Tipper and Guex, 1994, Ward and others, 2001)	NW EUROPE (Bloose and Page, 1997)	TETHYS (Krystyn, 1987)	
Hettangian (Basal)	<i>Pleuropsiloceras</i> <i>Kammerkarities</i> <i>primulus</i>	<i>Kammerkarites</i> spp.	?	<i>Kammerkarites</i>	<i>Kammerkarites</i>	<i>Kammerkarites</i>	
	No Ammonites	<i>Psiloceras</i> <i>polymorphum</i>	<i>Psiloceras</i> <i>rectocostatum</i> <i>P. primocostatum</i>	<i>Psiloceras</i> <i>primocostatum</i>	<i>Caloceras</i> <i>P. plicatum</i>	?	
		<i>Psiloceras pacificum</i> <i>Nevadaphyllites</i>	<i>Psiloceras tilmanni</i>	<i>Psiloceras</i> <i>pacificum</i> ?	<i>P. sampsoni</i> <i>P. planorbis</i>	<i>P. calliphyllum</i>	
		<i>Choristoceras minutum</i> <i>Psiloceras tilmanni</i> <i>Psiloceras marcouxi</i> <i>Odoghertyceras</i>	<i>Psiloceras tilmanni</i> <i>Odoghertyceras</i>	No Ammonites	<i>P. erugatum</i> <i>Neophyllites</i> ?	No Ammonites	
		<i>Psiloceras tilmanni</i> <i>Psiloceras spelae</i> <i>Rhacophyllites</i>	No Ammonites		No Ammonites		
		<i>Choristoceras shoshonensis</i> <i>C. crickmayi</i>	<i>C. cf marshi</i> <i>C. cf crickmayi</i>				
		<i>C. robustum</i> <i>C. marshi</i>			<i>Choristoceras marshi</i>		
		Rhaetian (Late)	<i>C. rhaeticum</i>	<i>Choristoceras nobile</i>	<i>Choristoceras</i> spp.	<i>C. ammonitiforme</i>	

Figure 8. Global correlation for the Triassic-Jurassic boundary.

DISCUSSION AND CONCLUSIONS

Composite assemblages for the Nevada section discussed here have been described by Taylor (1982) and Taylor and others (1983), while the sea-level curve in Gonzales and others (1996) is based upon assemblages inferred from that section. It appears that those sediments from the British Columbia sections (Carter, 1990, 1993) were deposited primarily in comparatively deep settings (Figure 11, Composite Assemblages D and E). The top of the Peril Formation there yields *Monotis*, while the lower part of the Sandilands Formation furnishes uncommon ammonites and poorly preserved uncommon bivalves (Carter, oral communication, 1998). The part of the Sandilands Formation yielding Hettangian ammonites has locally common ammonoids and some thin-shelled bivalves.

Composite assemblage assignments for the Oregon section at

Morgan Mountain are given in Figure 11. There, the earliest beds discussed in this report are in the Rail Cabin Argillite and were referred to the Columbianus Zone (Figure 3). The associated fauna consists of abundant ammonoids and the thin-shelled pteriomorph *Halobia*, locally common rhynchonellid brachiopods, and other rather small benthic bivalves. These indicate allocation to Composite Assemblage C(2). The uppermost beds of the Rail Cabin Argillite above this fauna are lacking in macrofauna, indicating assignment to Composite Assemblage E. The limestone member of the overlying Graylock Formation yields locally common ammonoids, a few coleoids, occasional thin-shelled pectinaceans such as *Agerchlamys*, and diminutive bivalves and gastropods. An assignment to Composite Assemblage C(2) or D(1) is indicated. The beds probably are predominantly in Composite Assemblage D(1)

since the benthic fauna (exclusive of pectinaceans) consists of juvenile or diminutive individuals. Taylor and others (1983) at first assigned the member to Composite Assemblage A on the basis of reports of reeflike bioclastic limestone from it and because "*Disconia*" in the upper member (along with lithology) suggested deposition of that unit in a "shallowing embayment transitional to an estuarine environment" (Dickinson and Vigrass, 1965). Subsequent investigation by author Taylor revealed that the "reef-like structures" are microcrystalline mud mounds, which may occur in comparatively deep water. Also, disconids are not necessarily indicative of shallow or estuarine waters, since they commonly occur in fully marine facies. The author found the upper member to be lacking in macrofauna and now favors a more offshore environment.

At Hole-in-the Ground (Figure 1, locality 3; Figure 4), the Rail Cabin Argillite having sporadic occurrences

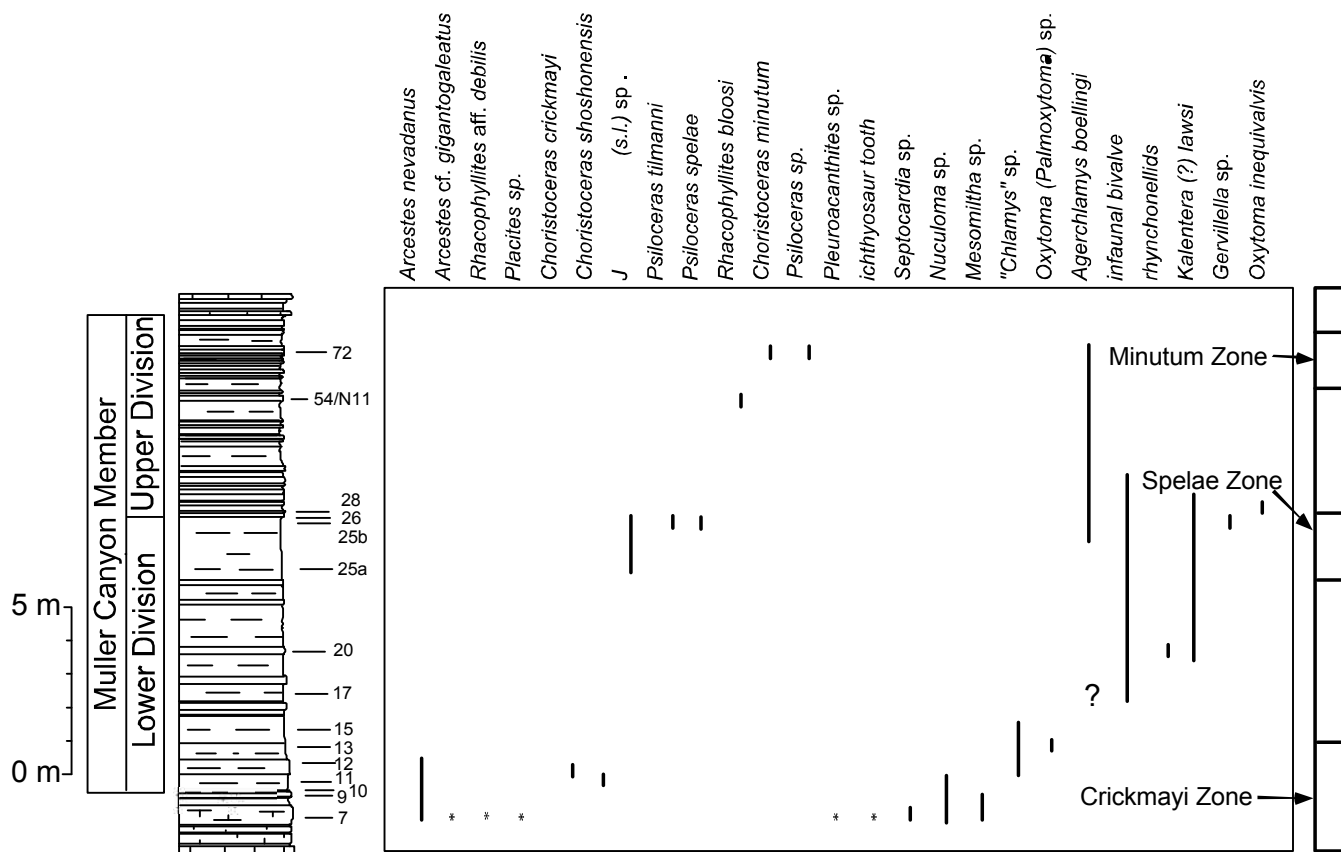


Figure 9. Stratigraphic section for the Muller Canyon Member at its type locality, Ferguson Hill (section e), New York Canyon area. Asterisk denotes float material.

of thin-shelled pteriomorph bivalves ranges from Composite Assemblage D to Composite Assemblage E. The lower member of the Graylock Formation at that locality lacks macrofauna and could be allocated to Composite Assemblage E. At Williams Reservoir (Figure 1, locality 4; Figure 6) the lower member lacking ammonites is composed of bioclastic crinoidal limestone and is referable to Composite Assemblage B, while the upper member having some ammonoids, a few thin-shelled pectinacean bivalves, and other rather small benthic bivalves probably ranges from Composite Assemblage C(2) in its lower portion to Composite Assemblage D (or possibly E) higher in the section.

The comparison of the composite assemblages and inferred sea-level curves in the principal sections in North America reveal that sedimen-

tation was deepest overall in the arc-related basins in Oregon and British Columbia. Transgressive-regressive curves based on composite assemblages are given in Figure 11 for the Oregon section as well as the others in North America for comparison. The curve pattern is, for the most part, similar to that given in Taylor and others (1983). The shallower water sections (Nevada and Sonora) indicate a regressive pulse between zones 3 and 4 (Figure 11). Overall, the uppermost Triassic is transgressive. A significant regression occurs in the upper part of the Hettangian Stage. In Sonora and Oregon, the regression is evident at lithologic boundaries where the overlying facies is clearly the shallower water one. In Nevada (New York Canyon area), ammonites drop out upsection in upper Hettangian beds, indicating a transition from

Composite Assemblage C to Composite Assemblage B with an upsection trend. The sections cumulatively suggest a transgression in the upper Columbianus or Cordilleranus Zone and a sharp regression at the base of the Newyorkensis Zone, followed by gentle transgression up to the top of the Triassic. The Hettangian has a sharp regression in its upper part. The shallow-water sections in Nevada and Sonora generally reveal more details of the transgressive-regressive curve than the deep-water ones from Oregon and the Queen Charlotte Islands. The Newyorkensis and late Hettangian regressions are clearly eustatic (Taylor and others 1983).

The record reveals that, in contrast to Europe, sedimentation across the Triassic-Jurassic boundary along the western margin of North America was continuous at certain localities. While the sections in the Queen

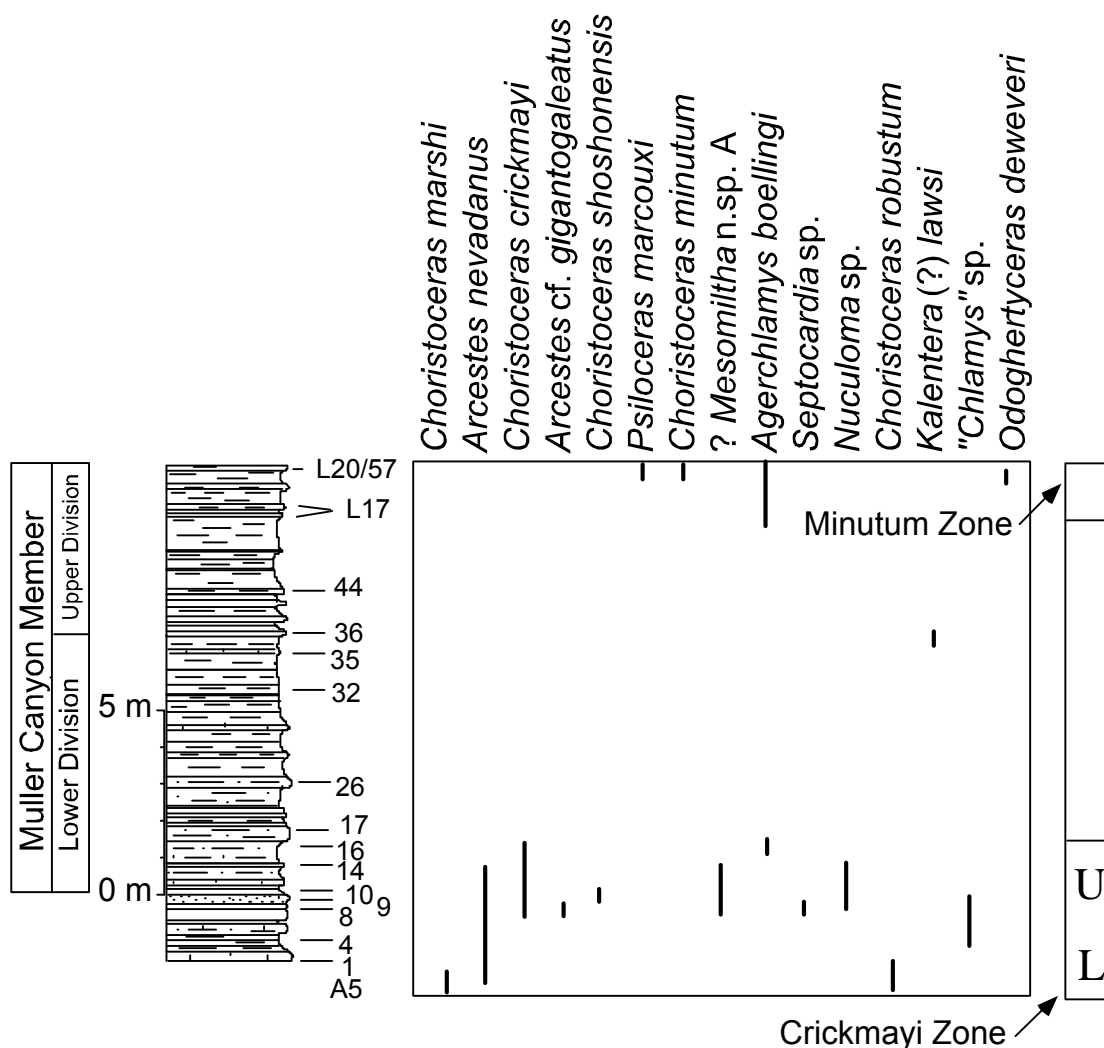


Figure 10. Stratigraphic section at Reno Draw (section d), New York Canyon area.

Charlotte Islands and in Oregon may represent uninterrupted sedimentation, they were too deep to support an abundant macrofauna upon which to base detailed correlations. In contrast, the continental-margin section in Sonora was a shallow-water one marked by a major depositional hiatus near the boundary. Only the Nevada back arc was of the appropriate depth to support a rich and diverse macrofaunal sequence spanning the boundary. The sequence in South America described by Hillebrandt (1997, 2000) comes closest to matching the Nevada section, but lacks refinement in the uppermost Triassic faunal sequence and appears to have a more significant faunal

hiatus near the boundary (Figure 8). These observations argue that the Nevada section is the ideal stratotype for the system boundary.

As discussed in Taylor and others (2000), the Gabbs Formation yields a low-diversity ammonoid fauna composed of 15 genera. In addition, most collection sites yielded only one to three species. The ammonite fauna from the formation is composed of genera that fall into few morphotypes, as follows: Those with (1) smooth, involute, compressed shells; (2) weakly ornate, involute, and slightly compressed or globose shells; (3) mid-volute smooth shells; and (4) serpenticones or heteromorphs. Lacking are mid-volute, ornate ammonoids that typi-

cally dominate faunas. Only the heteromorphs, which include uncoiled ammonoids such as *Choristoceras*, exhibit rapid turnover rates and were diversifying at the species level right to the end of the Triassic (Figure 7).

The low generic diversity and lack of mid-volute ammonites may indicate ammonoid communities that were under ecological stress (Taylor and others, 2000). Mesozoic heteromorphs made their first appearance near the end of the Triassic in the Cordilleranus Zone, and that event perhaps foreshadowed the final extinction event following Crickmayi Zone time. The final extinction event was sharp and can be observed just above the base of the

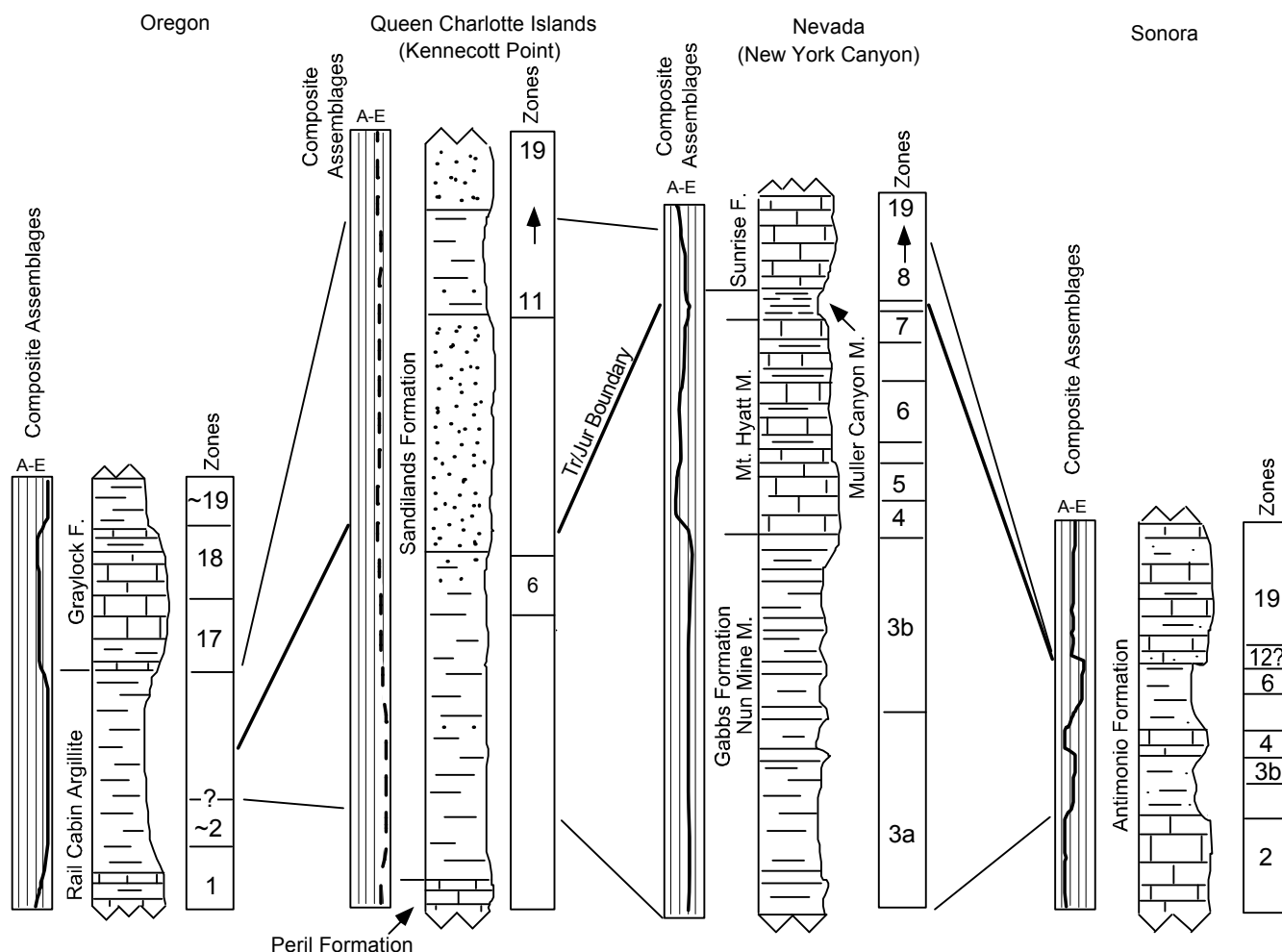


Figure 11. Correlation of North American Triassic/Jurassic boundary sections.

Muller Canyon Member, where numerous typically Triassic genera suddenly became extinct.

The heteromorphs are remarkable in that they were flourishing when most other ammonoids were waning at the end of the Triassic. The genus *Choristoceras*, in fact, persisted with the very first typically Jurassic ammonoids in the Minutum Zone before expiring. The overall ammonoid pattern indicates, then, that the ammonoid communities were waning over a period of time in the Late Triassic and that this deterioration culminated with an abrupt extinction at the end of Crickmayi Zone time.

This pattern of deterioration of ammonoids contrasts with our understanding of the bivalves (Laws, 1982) and radiolaria (Carter, 1993), namely, that the latter remained diverse prior to the terminal event at the end of Crickmayi Zone time. The ammonoids, however, have a higher trophic position than the radiolaria and bivalves and may have responded more quickly to environmental deterioration in latest Triassic times.

SYSTEMATICS

Repository for all specimens described below is the Northwest Museum of Natural History (NWMNH) in Portland, Oregon.

Bivalves

Family PECTINIDAE Rafinesque, 1815 Genus *Agerchlamys* Damborenea, 1993

Agerchlamys boellingi n.sp.

Plate 1: 1–4, 8–11; Plate 4: 1–3

Holotype: NWMNH No. 25510. Provenance: From lower part of Ferguson Hill Member, New York Canyon area (Fig. 1A, loc. d). Dimensions: H=29.5 mm, W=29.4 mm. Left and right valves.

Etymology: Named after Karen Boelling, for her contribution to our understanding of the geochemistry of the Volcano Peak Group.

Diagnosis: Ribbing fine; left valve with umbonal angle greater than 90°; radial ribbing weak on posterior ear,

shell in vicinity of byssal notch preserves only growth striae. Posterior auricle about $\frac{1}{2}$ to $\frac{2}{3}$ the length of the anterior auricle.

Description: Shell of moderate size; valves gently inflated, left valve more inflated than right valve. Anterior right auricle with fairly deep byssal notch. Posterior auricles more than half the length of anterior auricles. Posterior margin of posterior auricles steeply sloping, anterior margin of anterior auricle on left valve subvertical to gently overhanging. Antero-dorsal margin on right valve moderately concave; dorsal margins otherwise gently concave to straight. On right valve umbonal angle may at first be $<90^\circ$, but quickly widens with growth to $>90^\circ$; umbonal angle on left valve $>90^\circ$ degrees. Radial ribs very fine, threadlike, with relatively wide interspaces; intercalatory ribbing common; normally >50 radial ribs on a valve, concentric ribbing weaker than radial ribbing, although on some specimens concentric ribbing may be strong enough to result in reticulate ornamentation. Auricle preserves a few to several radial ribs which are weak to moderate in strength on anterior ears and faint on posterior ears. Shell in vicinity of byssal notch sculptured only by growth striae.

Discussion: This species is characterized by its fine and closely spaced radial ribbing which, in conjunction with comarginal ribbing, gives a delicate cancellate ornamentation. This species is similar in appearance to *A. wunshanae* Marwick from New Zealand and South America (Damborenea, 1993), which differs by having an anterior auricle shorter ($<\frac{1}{2}$ of length) than the posterior auricle. Specimens unequivocally assigned to the species occur in strata superjacent to the Crickmayi Zone. One specimen from the Crickmayi Zone (Figure 10, bed 16) has slightly less dense radial costation than is typical, while another shell fragment from the same level at stratigraphic section e-e' (Figure 9, bed 17) may also belong to this species.

Family PERMOPHORIDAE va de Poel, 1959
Subfamily PERMOPHORINAE va de Poel, 1959
Genus *Kalentera* Marwick, 1953

Kalentera (?) *lawsi* n.sp.
Plate 1: 5–7, 12, 13

Holotype: NWMNH 25484. Provenance: Gabbs Formation, near base of upper division of Muller Canyon Member, New York Canyon area, bed 28. Dimensions: L=49.3 mm, H=22.5 mm.

Etymology: Named after Richard Laws, who studied the bivalve fauna from the Gabbs Formation.

Diagnosis: Shell elongate, lunule small.

Description: Shell elongate, with rather small sub-terminal beaks; lunule small; escutcheon well defined; buttress present just anterior of the umbo. Anterior shell margin narrowly rounded; shell height greater in posterior half of valve; posterior border moderately to broadly

rounded. In some examples a vague broadly rounded ridge runs from umbo to postero-ventral shell margin. Concentric growth striae are the only conspicuous ornamentation; some examples preserved one to two faint radial ribs close to dorsal margin.

Discussion: The Nevada material differs from the Rhaetian species *Curionia curianii* (Hauer) from Europe in having a markedly more elongate shell and smaller lunule. Faint radial ribs in the dorsal area suggest a likely assignment of this species to the Jurassic *Kalentera*, although firm generic allocation cannot be made without preserved hinge structures.

Ammonites

Family SAGENITIDAE Spath, 1951
Genus *Sagenites* Mojsisovics, 1879

Sagenites striata n.sp.
Plate 3: 4, 8, 19

Holotype: NWMNH 25271. Provenance: Gabbs Formation, lower part of Nun Mine Member at section c-c' (Figure 1A). Dimensions: Diameter=78 mm.

Etymology: Named for the prevalent striate ornamentation on the shell surface.

Diagnosis: Shell compressed; weak longitudinal ribbing conspicuous in ventral area, faint or absent on whorl side.

Description: Whorl section, while partly crushed appears to have been quite high and subtrigonal; umbilicus narrow, umbilical wall subvertical, shoulder sharply rounded. Costation strongly prorsiradiate, quite gently falcoid, strongest near mid-flank; on lower $\frac{2}{3}$ flank consists of moderately spaced primaries of irregular strength; secondary ribbing on upper flank dense, has concave flexure in ventro-lateral area, thus not strongly projected across venter; on body chamber radial ornamentation consists of faint primaries and growth striae. Longitudinal ribbing weak but well defined on internal mold as well as where shell preserved near top of flank and over venter; greatly reduced in strength on body chamber. **Discussion:** *Sagenites striata* n.sp. is most similar in appearance to *Sagenites* nov. f. ind. (Mojsisovics, 1899, p. 41, pl. 11, Figure 10) from the Himalayas. That form differs from the new species in having a quite gently rounded umbilical shoulder, less distinction in strength of longitudinal ribbing between the whorl side and the ventral region, and more projected costation in the ventro-lateral area.

The holotype of *S. striata* is a float specimen from the Nun Mine Member and was found in a block containing a specimen of *Peripleurites* n.sp.

Sagenites minaensis n.sp.
Plate 3: 1–3, 5, 6

Holotype: NWMNH 25274. Provenance: Gabbs Formation near top of Nun Mine Member at section a-a' (Figure 1A); Dimensions: Diameter=85 mm.

Etymology: Named for the town of Mina.

Diagnosis: Narrowly umbilicate; on upper flank of phragmocone ornamentation with well-defined reticulate pattern; spiral ribbing noticeably stronger than radial ribbing on lower flank.

Description: Inner whorls (up to 8 mm shell diameter) have strongly depressed subovate section and strongly inflated flank with no umbilical shoulder; adorally shoulder becomes defined (as early as 15-mm shell diameter), and whorl section becomes less depressed; outer whorls have broadly rounded venter; at that stage umbilicus narrow to minute, wall overhanging, shoulder rounded but well defined. On inner whorls (to at least 18 mm shell diameter) radial ribbing is clearly most prominent ornamentation, quite irregular in strength and somewhat irregular in spacing, strongest in mid-flank region, prorsiradiate, quite gently convex over venter; secondary ribs common; ribs in nucleus (shell diameter 5–6-mm) sub-bullate low on flank. On outer part of nucleus weak, dense, longitudinal ribs may appear. On intermediate whorls longitudinal ribs widest and most prominent ornamentation on lower flank; farther up whorl side the prorsiradiate, gently flexed radial ribbing becomes more prominent and subequal in strength to longitudinal ribs; the effect is a delicate reticulate ornamentation; radial ribs weakly convex over venter; beyond approximately 60-mm shell diameter, radial ribs begin to decrease in strength, while longitudinal ribs become broader; eventually these, too, appear to fade.

Discussion: This new species is referable to the *reticulati* species group of Mojsisovics (1893) and is similar in appearance to several “species” allocated to it. *S. reticulatus* is considerably more weakly ornate at equivalent shell dimensions and *S. subreticulatus* is not so conspicuously reticulate on the upper flank, the radial ribs being substantially broader and more poorly defined than in the new species. *S. werneri* Mojsisovics has a subtrigonal whorl section and less well defined radial ribs on the adapical part of the final whorl and is more widely umbilicate. *S. theorori* Mojsisovics is perhaps most similar in ribbing at large shell dimensions. It, too, has an outer whorl that appears to be significantly more widely umbilicate and has radial ribs that are less continuous on the outer flank. *S. princeps* is similar in appearance but has broader, less well defined radial ribs and a slightly wider umbilicus.

Family ARCESTIDAE Mojsisovics, 1875

Genus *Arcestes* Suess, 1865

Arcestes cf. *gigantogaleatus* (Mojsisovics)

Plate 1: 15–16

Specimen: NWMNH 25486. Provenance: Graylock Formation, Camp Faraway, Oregon (Figure 1B, locality 1).

Description: A single large specimen preserving adapical end of body chamber. Phragmocone globose, narrowly umbilicate, whorls strongly depressed; four shallow

slightly flexuous, radial constrictions occur on last whorl where shell missing; rib on adapical side of constriction on venter and whorl side most pronounced where shell material present. Fine growth striae only other ornamentation preserved; septal suture complexly incised but not traceable.

Discussion: The specimen is a close match to *A. gigantogaleatus* as represented in Alpine Europe and Nevada. The Oregon specimen differs, however, in having a slightly wider umbilicus, which is about 15 percent of the diameter (at a shell diameter of 114.2 mm). In contrast, Nevada examples of *A. cf. gigantogaleatus* have an umbilicus only 9–10 percent of the diameter at similar shell dimensions. The alpine material is also narrowly umbilicate like the Nevada specimens. The Oregon specimen came from a calcareous sandstone block from the Graylock Formation at Camp Faraway.

Superfamily CLYDONITACEAE Mojsisovics, 1879

Family METASIBIRITIDAE Spath, 1951

Genus *Gabboceras* n.gen.

Type species: *Gabboceras delicatum* n.sp.

Diagnosis: Weakly ornate; one row of fine lateral spines just below mid-flank, one row of dense, exceptionally delicate clavae in ventro-lateral area. Suture goniotitic.

Discussion: Affinity of *Gabboceras* with *Lissonites* (Tozer 1979) is suggested through similar development of lateral nodose ornamentation. *Lissonites* differs in numerous details. It has a stouter whorl section, is much more coarsely ornate, and ribbing is not so strongly prorsiradiate; in addition, it has umbo-lateral nodes (on coarsely ornate material representing a new species from Nevada), two rows instead of one row of ventro-lateral nodes, bullate instead of clavate ventro-lateral nodes, and a septal suture with an undivided external lobe (E). These dissimilarities in ornamentation, while sufficient for generic level distinction, are not exceptionally great, either. Overall, strong affinities are clearly indicated. A coarsely ornate new species of *Lissonites* from the southern end of the North Humboldt Range, Nevada, for example, does reveal affinities. Coarsely ornate material of the new species of *Lissonites* has the full complement of the four sets of nodes. Finely ornate material on the other hand has only two rows, corresponding in position to those of *Gabboceras*. Affinities with *Nassichuckites* are also suggested. This genus is considerably more strongly ornate and lacks lateral nodes, but there is close correspondence in the suture. *Gabboceras* is a weakly ornate derivative of *Lissonites* or perhaps *Nassichuckites*.

Gabboceras delicatum n.sp.

Plate 3: 7, 9, 10

Holotype: NWMNH No. 25354. Provenance: Gabbs Formation, top of Nun Mine Member, New York Canyon area; Dimensions: Diameter=16 mm.

Etymology: Named for its delicate ornamentation.

Diagnosis: Weakly ornate; inner flank with row of nodes, ventro-lateral area with row of exceptionally fine, closely spaced clavate nodes; ribbing and striae on flank strongly prorsiradiate.

Description: Shell small, moderately evolute, with compressed subovate whorl section; adapical part of body chamber preserved on several specimens. Ribbing and striate ornamentation strongly prorsiradiate; moderately to widely spaced ribs well defined only on inner flank; they vary in density on later whorls between 8 and 11 to the half-volution; just below mid-flank, they carry bullate and sometimes pointed delicate nodes; ribs fade quickly high on flank above nodes; ventro-lateral area carries row of very strongly prorsiradiate, imbricate clavae having a finely chorded appearance; faint secondary ribbing at larger shell dimensions present just below ventro-lateral clavae. Striate ornamentation has approximately same trajectory above clavae (on venter) as on upper flank and follows a gently convex course across venter. Suture goniotitic; E with median saddle shorter than or subequal in depth to lateral lobe (L).

Discussion: Two of the eight examples available for study are quite weakly ornate in that one lacks lateral nodes and is at best faintly ribbed in the mid-flank region, while another preserves faint nodes only on the outer half-volution. Lateral nodes were observed at shell diameters as small as 3 mm on relatively ornate material.

Family CYCLOCELTITIDAE Tozer, 1979
Genus *Cycloceltites* Mojsisovics, 1893

Cycloceltites tozeri n.sp.
Plate 4: 7–12

Holotype: NWMNH No. 25362. Provenance: Gabbs Formation, lower division of Mount Hyatt Member, New York Canyon area. Dimensions: Diameter=40.7 mm.

Etymology: Named in honor of E.T. Tozer and his magnificent contribution to the study of Triassic ammonoids.

Diagnosis: Shell with dense ribbing on the outer as well as inner volutions.

Description: Shell serpenticonic in coiling; whorl section of nucleus (up to approximately 4- to 5-mm shell diameter) subcadicone; adorally whorl section becomes subcircular but with incipient accentuation of ventro-lateral and umbo-lateral regions; outer whorls most commonly quite weakly depressed, but finely ornate specimens may have slightly compressed whorl section. Subcadicone nucleus with rounded lateral edge that bears fine, sharp-crested, prorsiradiate, bullate nodes; adorally these fade and migrate within ½ volution to ventro-lateral rib swellings; one specimen with well-preserved inner whorls reveals weak parabolic lines subparallel to

growth lines, which may, however, cut across ribs; costation concave on lower flank, prorsiradiate and gently convex on mid-flank to just below ventro-lateral region; ribbing on juvenile prorsiradiate, subradial on intermediate and outer whorls; costation dense, quite gently flexuous, most commonly strongest on mid- to outer flank; ribbing simple and for most part regular in spacing and strength; outer whorl may have ribbing somewhat irregular in strength and includes rare intercalatory and bifurcate costae; ribs do not cross venter on inner and intermediate whorls on most specimens, but one small example does have ribbing continuous across venter at approximately 15-mm shell diameter; outer whorl may have ribbed venter, but ribs most commonly weakest near mid-line of venter; ribs not projected where they cross venter.

Discussion: Mojsisovics (1893) described several alpine species of *Cycloceltites* represented for the most part by small specimens that either do not compare well with the new species or provide little basis for accurate comparison. Of the alpine material equivalent in size with the Nevada specimens, *C. arduini* (Mojsisovics) is most similar. That form is readily differentiated from *C. tozeri*, which is much more densely ribbed, there being commonly 7–10 more costae per half-whorl on the intermediate and outer volutions.

Family Choristoceratidae Hyatt, 1900
Genus *Vandaite* Tozer, 1979

Vandaite newyorkensis n.sp.
Plate 3: 11–13, 18

? *Choristoceras suttonense* Clapp and Shimer 1911, p. 434, pl. 40, Figures 4,6; Smith 1927, p. 98, pl. 105, Figures 5, 6; Tozer, 1967, p. 39, 79; 1979, p. 134, pl. 16.1, Figures 1–3; Figure 16.1K.

Holotype: NWMNH No. 25412. Provenance: Gabbs Formation, base of Mount Hyatt Member, New York Canyon area. Dimensions: Diameter=36.2 mm.

Etymology: Named for New York Canyon.

Diagnosis: Large species with a strong tendency for markedly prorsiradiate ribbing on the inner whorls.

Description: Inner whorls subcircular, outer whorls subovate to subcircular; last whorl detached from preceding volution, ribbing gently sigmoidal, upright to gently reclined; small bullate swellings in ventro-lateral area confined to inner whorls, where ribs commonly cross venter; at larger shell dimensions ribs become increasingly strong over venter; at largest shell dimensions no indication of ventral interruption, and bullae lost or vague. Septal suture with lateral lobes simple to weakly bifid; saddles broadly rounded.

Discussion: The Nevada material is similar in appearance to the Canadian *Choristoceras suttonense* Clapp and Shimer. However, the holotype of the latter is nothing more than a whorl fragment to which meaningful comparison can not be made. *C. suttonense* is therefore considered to be a *nomen nudum*. The septal suture from specimens from the Gabbs Formation show some variability in that the lateral lobes are entire on one specimen and slightly incised on the other.

Genus *Choristoceras* Hauer, 1865

Choristoceras shoshonensis n.sp.
Plate 3, 14–17

Choristoceras cf. *C. crickmayi* Tozer 1979,
pl. 63, Figure 5.

Holotype: NWMNH No. 25387. Provenance: Top of Mount Hyatt Member at Milton Canyon, Shoshone Mountains. Dimensions: Diameter=27.3 mm.

Etymology: Named after Shoshone Mountains.

Diagnosis: Inner whorls serpentic in coiling, ribbing fal-coid and strongly rursiradiate.

Description: Inner whorls markedly serpentic in coiling, with low whorl expansion rate; outer whorl detached. Whorl section of phragmocone weakly depressed to subcircular; that of body chamber may be compressed; ribbing weakly to markedly fal-coid, weakly to most commonly strongly rursiradiate, commonly gently concave on lower flank; ribs gently rursiradiate to less commonly radial in ventro-lateral area where they intersect weak bullate nodes; costation continuous across venter, where it increases in height adorally; midline of dorsum smooth or exhibits exceptionally vague ribbing crossing extern-side; septal suture with E shorter than L, which is longest of the two lateral lobes; lobes simple, lateral saddles broadly rounded.

Discussion: The fal-coid ribbing readily distinguishes this species from others in the genus in that there is a greater tendency to possess a convex rather than concave flexure on the lower flank. There is some similarity with *C. cf. crickmayi* Tozer and *C. cf. nobile* Mojsisovics as figured in Chong and Hillebrandt (1985) from South America. These differ in their less serpentic inner whorls and a rib trajectory that is not markedly rursiradiate. Rib counts for the half whorl (measured at 2-cm shell diameter, 11 specimens) range between 18 and 22 costae, although occasional fragments suggest somewhat denser ribbing.

Choristoceras shoshonensis was recovered from near the top of the Mount Hyatt Member in the Shoshone Mountains. Crushed specimens are locally abundant at the base of the Muller Canyon Member in the New York Canyon area. Some New York Canyon examples are not noticeably detached, but apparent dissimilarity may be due to shell crushing.

Choristoceras robustum n.sp.
Plate 4, 4–6

Holotype: NWMNH No. 25515. Provenance: Near top of Mount Hyatt, Gabbs Valley Range, New York Canyon area, section d-d' (Figure 1). Dimensions: Diameter=47.2 mm.

Etymology: Named for robust ribbing.

Diagnosis: Ribbing may be coarse and have strong bullate nodes in ventro-lateral area; septal suture with markedly bifid E, L, and second lateral lobe.

Description: Shell large, outer preserved whorl attached, inner whorls probably subcircular, adoral part of outer preserved whorl compressed subrectangular; ribs strong, quite gently flexed, subdirect to strongly rursiradiate, merge into strong bullate nodes in ventro-lateral area and persist, at best, as low broad undulations (not well-defined ribs) in mid-ventral region; septal suture with narrow E not quite as long as L; both are strongly bifid, as is case with shorter second lateral lobe.

Discussion: The hypodigm consists of four specimens. The smallest specimen indicates a much finer ribbed individual than the holotype. This robust and distinctive species does not compare well with any from Europe. Its affinities are probably with the older *Vandaites newyorkensis*, which differs markedly in its less quickly expanding whorls with growth, less prominent ventral nodes on the inner whorls, ribbing on the outer whorl which crosses the venter without interruption, and simpler suture.

Choristoceras n.sp.
Plate 4, 16–19

Specimen: Two fragments of same specimen. NWMNH No. 25519. Provenance: Mount Hyatt Member, Gabbs Valley Range, New York Canyon area.

Discussion: The two fragments have a compressed sub-ovate whorl section, gently flexed and reclined ribbing, and prominent ventro-lateral bullate ribbing which is dramatically reduced in strength over the venter. This species has a significantly slower whorl expansion rate than that of *Choristoceras robustum*, but is similar in ribbing style and ventral features, most notably the sharp bullate nodes and interrupted venter at large shell dimensions. This material is intermediate in morphology between *C. robustum* and *Vandaites newyorkensis*. *Choristoceras* n.sp. probably came from an intermediate stratigraphic level in the Mount Hyatt Member as well (perhaps Tozeri Horizon). The fine greenish-gray calcitic matrix is unlike that of the basal bioclastic beds of the member, where *Vandaites newyorkensis* is found, and the dark gray limestone matrix at the top of the member, where *Choristoceras robustum* occurs.

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(Continued on page 28)

PLATE I

(Specimen numbers refer to Northwest Museum of Natural History. Sizes are natural unless indicated.)

1–4, 8–11. *Agerchlamys boellingi* n.sp.

1. No. 25474, H= 36.4 mm, W= 38.9 mm, lower part of Graylock Formation at Camp Faraway, loc. CF1, left valve, Morganense zone;
2. No. 25475, Ferguson Hill Member, Sunrise Formation, Section e-e', bed 90, left valve;
3. No. 25476, lower part of Graylock Formation at Camp Faraway, loc. 17, left valve, Morganense zone;
4. No. 25477, lower part of Graylock Formation at Camp Faraway, loc. CF1, left valve, Morganense zone;
8. No. 25479, lower part of Muller Canyon Member, Gabbs Formation, Section d-d', bed 16, left valve, Crick-mayi Zone;
9. No. 25480, Muller Canyon Member, Gabbs Formation, Section e-e', bed 28, right valve, Spelae Zone;
10. No. 25481, same locality as No. 25480 (bed 28), right valve;
11. No. 25482, same locality as No. 25480 (bed 28), left valve.

5–7, 12, 13. *Kalentera* (?) *lawsi* n.sp.:

- 5–7. No. 25517, same locality as No. 25480 (bed 28);
12. No. 25483, same locality as No. 25480 (bed 28);
13. Holotype No. 25484, H=22.5 mm, L=49.3 mm, same locality as No. 25480 (bed 28A).

14. *Monotis* (*Pacimonotis*) *subcircularis*

No. 25485, Rail Cabin Argillite at Hole-in-the-Ground, locality 7637, Cordilleranus Zone.

15, 16. *Arcestes* cf. *gigantogaleatus* (Mojsisovics)

No. 25486, from exotic block in Graylock Formation at Camp Faraway, locality 7044, Rhaetian (x 0.67).

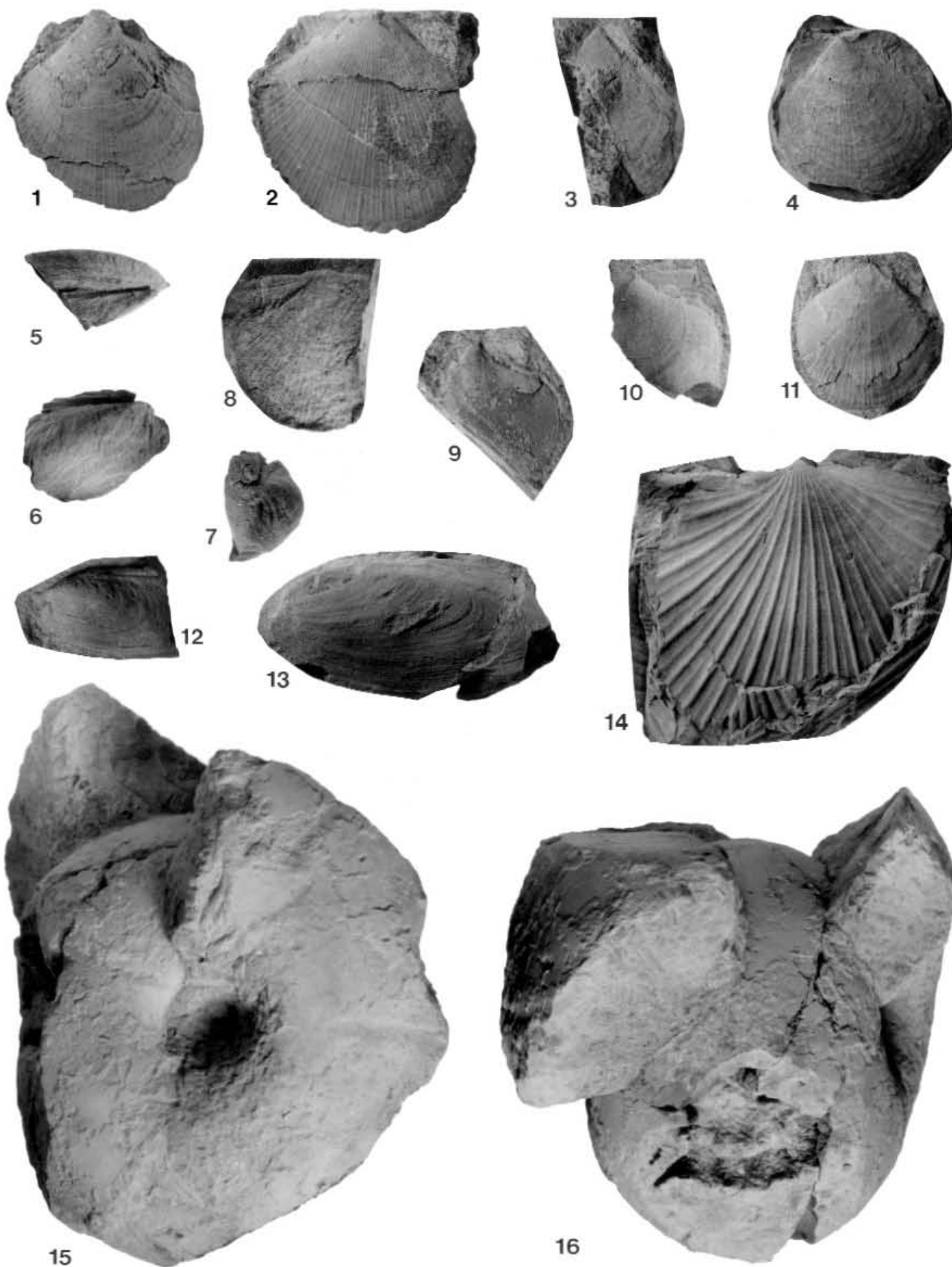


PLATE 2

(Specimen numbers refer to Northwest Museum of Natural History. Sizes are natural unless indicated.)

1, 2, 4. *Gyrophioceras morganense* Taylor

1, 2. No. 25235, Graylock Formation, locality 73, Morganense Zone;

4. No. 25487, Graylock Formation, locality 6912, Morganense Zone.

3, 12, 13. *Franziceras graylockense* Taylor

3. No. 25233, Graylock Formation, locality 6923, Morganense Zone

12, 13. No. 25048, locality 6923, Morganense Zone (x 1.5).

5. *Paradiscamphiceras athabascanense* Taylor

No. 25200, Graylock Formation, locality TG8, Oregonensis Zone.

6, 7. *Badouxia columbiae* (Frebold)

No. 25488, Graylock Formation, Williams Reservoir, Canadensis Zone.

8. *Metophioceras* aff. *rursicostatum* (Frebold)

No. 25489, Graylock Formation, Williams Reservoir, Canadensis zone.

9–11. *Paradiscamphiceras dickinsoni* Taylor

9. No. 25199, Graylock Formation at Camp Faraway, locality 17, Morganense Zone;

10, 11. No. 25188, Graylock Formation, Morganense Zone.

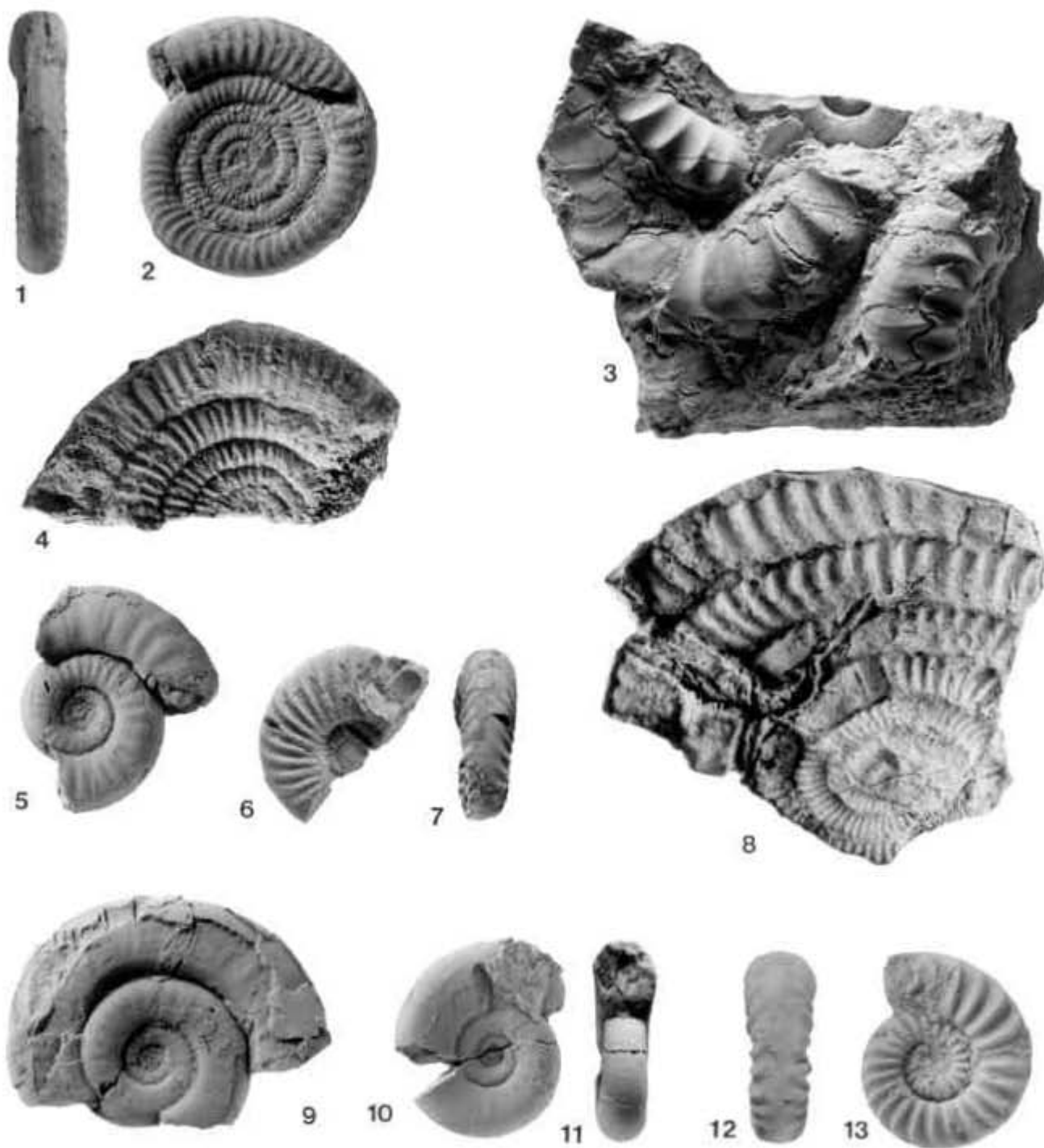


PLATE 3

(Specimen numbers refer to Northwest Museum of Natural History. Sizes are natural unless indicated.)

1–3, 5, 6. *Sagenites minaensis* n.sp.

- 1–3. Holotype, No. 25274, shell diameter=85 mm, Gabbs Formation, near top of Nun Mine Member at section a-a', New York Canyon area, specimen partially compressed diagenetically, Minaensis Subzone;
5, 6. No. 25275, same locality as No. 25274.

4, 8, 19. *Sagenites striata* n.sp.

- 4, 19. Holotype, No. 25271, shell diameter=78 mm, Gabbs Formation, lower part of Nun Mine Member at section c-c', Striata Subzone;
8. No. 25272, same locality as No. 25271.

7, 9, 10. *Gabboceras delicatum* n.gen. et sp.

7. No. 25518, same location as No. 25354, Minaensis Subzone (x 2.0);
9, 10. Holotype, No. 25354, shell diameter=16 mm, Gabbs Formation, near top of Nun Mine Member at section a-a', New York Canyon area, same locality as No. 25274, Minaensis Subzone (x 2.0).

11–13, 18. *Vandaite newyorkensis* n.sp.

- 11–13. Holotype, No. 25412, shell diameter=36.2 mm. Gabbs Formation, base of Mount Hyatt Member, New York Canyon area, Newyorkensis Zone;
18. No. 25408, Gabbs Formation, base of Mount Hyatt Member, New York Canyon area, outer whorl diagenetically distorted, Newyorkensis Zone.

14–17. *Choristoceras shoshonensis* n.sp.

- 14, 15. Holotype, No. 25387, shell diameter=27.3 mm, Gabbs Formation, top of Mount Hyatt Member at Shoshone Mountains, Milton Canyon, Crickmayi Zone;
16, 17. No. 25388, Same locality as No. 25387.

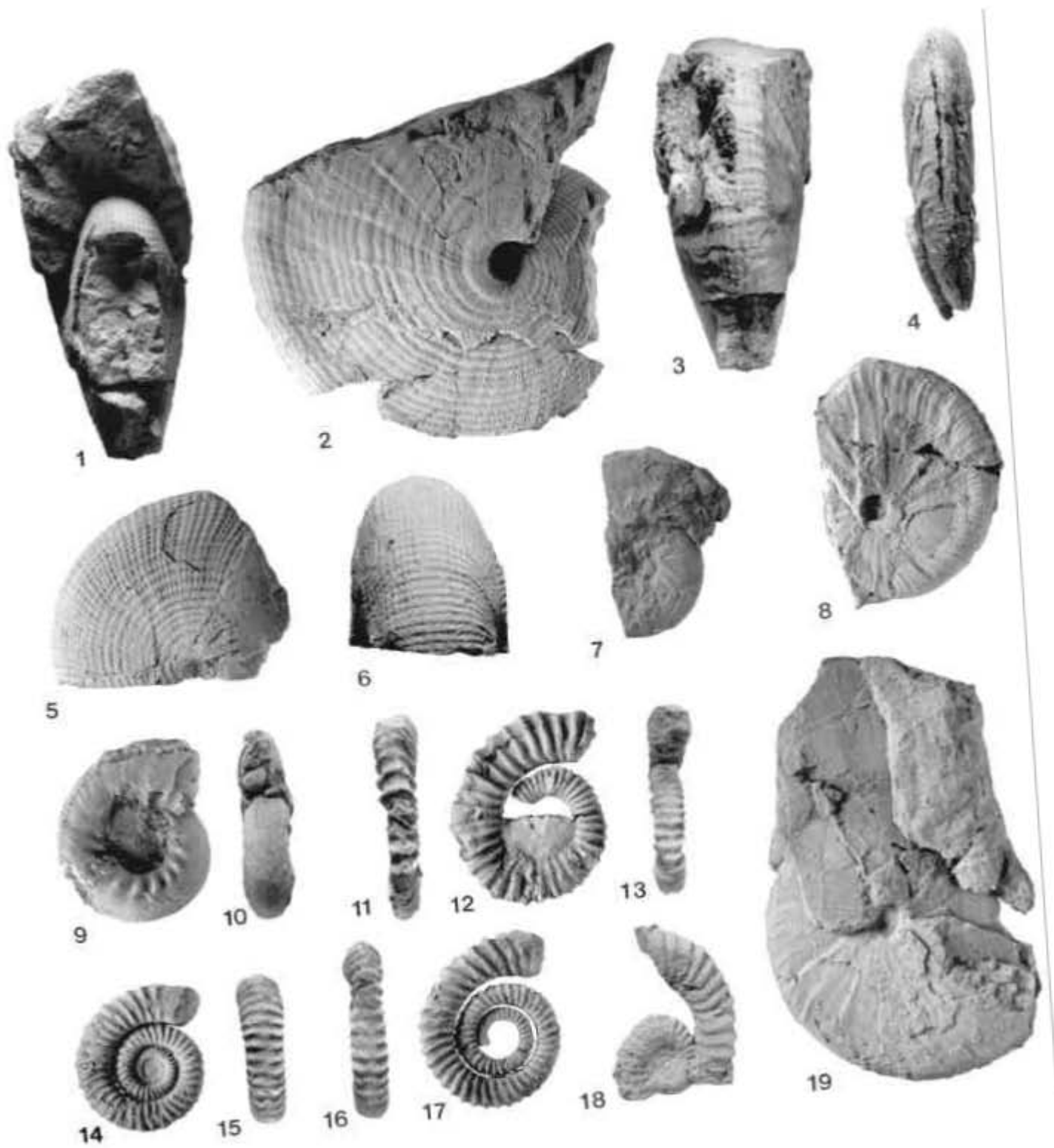


PLATE 4

(Specimen numbers refer to Northwest Museum of Natural History. Sizes are natural unless indicated.)

1–3. *Agerchlamys boellingi* n.sp.

1. Holotype, No. 25510, Sunrise Formation, lower part of Ferguson Hill Member at section d-d', New York Canyon area, left and right valves, Hettangian;
2. No. 25512, Sunrise Formation, lower part of Ferguson Hill Member at section d-d', New York Canyon area, Hettangian;
3. No. 25511, Gabbs Formation, Muller Canyon Member at section d-d', Minutum Zone.

4–6. *Choristoceras robustum* n.sp.

- 4, 5. Holotype, No. 25515, Gabbs Formation, approx. 1 m below top of Mount Hyatt Member at section d-d', New York Canyon area, Crickmayi Zone;
6. No. 25514, same locality as holotype.

7–12. *Cycloceltites tozeri* n.sp.

- 7, 8. Holotype, No. 25362, shell diameter=40.2 mm, Gabbs Formation, lower division of Mount Hyatt Member at section b-b', bed G46, New York Canyon area, Tozeri Horizon;
- 9, 10. No. 25363, same locality as holotype;
- 11, 12. No. 25365, same locality as holotype.

13–15. *Choristoceras Rhaeticum*

13. No. 25513, Gabbs Formation, Mount Hyatt Member at section b-b', New York Canyon area, Rhaeticum Zone;
- 14, 15. No. 25382, Gabbs Formation, Mount Hyatt Member at section b-b', New York Canyon area.

16–19. *Choristoceras* n.sp.

- No. 25519, Gabbs Formation, Mount Hyatt Member, New York Canyon area.



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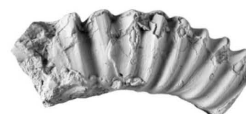
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(Fossils—continued from page 19)

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THESIS ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that in our opinion are of general interest to our readers.

*While reserving the right to determine the desirability of each acquisition, the Department is interested in purchasing two copies of each accepted master's thesis or doctoral dissertation, bound, and complete, for the amount of \$150 or \$200, respectively, if such a thesis or dissertation concerns the geology of Oregon. Part of the acquisition will be the right to publish the abstract in *Oregon Geology*.*

Geochemistry, stratigraphy, and provenance of the Portland Hills Silt in the Tualatin Mountains, Portland, Oregon, by J.L. Lawes III (M.S., Portland State University, 1997), 243 p.

Soil morphology and geochemistry of loess were investigated at nine sites in the Tualatin Mountains west of Portland and at additional sites in The Dalles, eastern Washington, and Puget Sound. A total of forty samples was examined, using Instrumental Neutron Activation Analysis (INAA).

Stratigraphic relationships and soil development suggest that the Portland Hills Silt (PHS) ages of Lentz (1977) be revised. The age of the PHS ranges from 12,000 to at least 960,000 years before present.

The geochemistry of the PHS supports the Lentz (1977) hypothesis of the PHS as a loess of continental origin. Thorium/scandium ratios in the PHS are in the continental range of 0.8 to 1.2 Th/Sc. This contrasts with the 0.2 to 0.5 Th/Sc ratio more typical of arc volcanics such as Boring Lava.

Soil properties and INAA data suggest that the 53rd Street PHS contains four episodes of loess deposition with immature soil horizon development. Paleosol clay enrich-

ment is typically less than 25% by weight and shows considerable randomness between paleosol and loess. Harden indices for paleosols ranged from 0.09 to 1.01, similar to the Holocene and late Pleistocene soils of Harden (1982). Large cation mobilization, particularly sodium, appears to be a good indicator of soil formation. Lack of similar eluviation of potassium and rubidium indicate that the 53rd Street paleosols are relatively immature.

The geochemical similarity between the PHS and deeper silty sediments on the West Hills previously described as Helvetia Formation by Schlicker and Deacon (1967) or "Sandy River Mudstone-equivalent" by L.R. Squier (1993) suggests that these sediments are an ancient PHS.

The 12,000- to 15,000-year-old surface soils (Birke-land, 1984) observed at Elm Street and 53rd Street suggest the likelihood that the uppermost, one- to five-meter-thick loess may incorporate sediment from Missoula Flood silts.

Basaltic volcanism and tectonics of the High Lava Plains, southeastern Oregon, by Brennan T. Jordan (Ph.D., Oregon State University, 2001), 218 p.

The High Lava Plains province (HLP) of southeastern Oregon is a Miocene to Recent volcanic upland characterized by widespread basaltic volcanism and west-migrating rhyolitic volcanism. New ⁴⁰Ar/³⁹Ar ages for HLP rhyolites demonstrate that the trend of migrating rhyolitic volcanism is robust, reflecting westward migration at a rate of ~35 km/m.y. from 10 to 5 Ma, and ~15 km/m.y. after 5 Ma. This pattern mirrors the trend of northeastward migrating silicic volcanism of the Snake River Plain to the Yellowstone Plateau. HLP basaltic volcanism was relatively continuous with episodes of heightened activity at ~7.6, ~5.9, and 2-3 Ma. The 7.6 Ma event coincided with initiation of High Cascades vol-

(Continued on page 33—Thesis Abstracts)

Mercury contamination associated with abandoned mines

by Randall L. Moore, Reclamationist, Oregon Department of Geology and Mineral Industries, Mineral Land Regulation and Reclamation Program

Mercury can be introduced into the biological environment both by natural processes and by mining activity. The mobility and availability of mercury to plants and animals is dependent on complex interactions of mineralogy, chemistry, and bacterial activity—conditions that may vary dramatically with distance from the source. The many forms of mercury have different levels of toxicity, ranging from benign to very harmful, and the hazard posed by a mercury occurrence must be evaluated by a comprehensive sampling program to determine forms and availability specific to the site.

Potential mercury contamination related to mining activities can occur around two types of historic mining within the State. Oregon has seen mine production from both mercury (Hg) and gold (Au) mines, which are potential sources of human-related mercury contamination. Conditions related to these mines have the potential to introduce elevated levels of mercury to the environment. Elevated mercury levels related to human activity are the result of the mining and processing of mercury ores and the processing of gold ores (naturally occurring mercury discharge may be related to both of these types of mines). While such sites are a potential problem for mercury introduction into the environment, the full extent of any human-related contamination is not fully understood at this time.

Oregon has seen an active history in lode mine production of both mercury and gold as well as placer production of gold. Development of the mines occurred at the turn of the century and extended until the 1940s for the gold production and into the 1950s for the production of mercury. The deposits hosting these metals occur in fairly well defined geologic settings and mineral belts. Mines within the same belt tend to have formed



Almeda Mine near Galice in Josephine County. The undated photo shows one of the largest gold mines in this area. Ore was mined and processed here mainly between 1911 and 1916 and again in 1940-1941. Such mining operations today represent potential sources of contaminants.

by similar processes, have similar geologic settings, associated elements, and host rock geochemistry.

Mercury production centered around two dominant belts, one located in southwestern Oregon and the other in central Oregon. Both locations saw production into the 1950s, with most of the production occurring between the 1920s and the 1950s. The main ore of mercury is cinnabar (HgS). The mercury content of cinnabar is 86 percent, and this vermilion-red ore has been exploited since ancient times, initially as a pigment and later for its metal value. Mercury deposits are generally associated with recent volcanic and hot springs activity. In addition, mercury is commonly found at or near the edges of serpentine belts in southern Oregon and northern California.

Mercury was extracted from the cinnabar ore by crushing and roasting and then recovered through dis-

tillation. This process is called calcination, and the waste rock left behind is referred to as calcine. The primary processing method consisted of heating the ore to 600°–700°C to volatilize the mercury. This was followed by a condensing process to recover the liquid elemental mercury. Since ores were typically processed at the mine site and only rarely sent to a central processing facility, the amount of calcines left at a mine site usually reflects the amount of ore that was mined.

Roasting the ore resulted in the oxidation of iron sulfides (FeS₂), causing the calcines to have a characteristic red color. Invariably, the calcine waste still contains some residual, soluble mercury that may leach into the environment. In fact, through its oxidizing effect, the roasting process often makes this residual mercury more accessible to the environment.

Historic gold mines are spread over a much wider geographic area than the mercury mines. Mining was scattered across the state, with production centered in southwestern Oregon, the Western Cascades, central Oregon, and portions of eastern Oregon. Gold miners used mercury as an amalgam in the processing of ores. The gold-bearing material was crushed and often treated with mercury to form gold amalgam. This product was then heated in a retort, volatilizing the mercury, which was then condensed and reused. Due to inefficiencies and poor handling practices, large amounts of both mercury vapor and liquid often escaped into the environment. While not all gold mines employed the practice of amalgamation, a significant number of them used mercury as a final step in collecting small particles of gold. The result of this practice was that elevated mercury levels were left in both waste dumps and streams located near the processing sites. The mercury associated with these sites is generally in elemental form, though some amount was oxidized during the roasting process.

Mercury and gold districts have elevated background levels of mercury before any mining activity begins, and some natural processes always contribute to mercury introduction into the environment. The natural sources of mercury inputs to the environment are significant contributors, greater than the human contributions, especially in the mine areas where elevated mercury levels exist near the surface. The contribution of mercury associated with human activities is a matter of debate. In part, this is because it is difficult to separate mercury that is derived from past human releases and that derived from natural inputs. Recent studies, however, have shown that a portion of the mercury introduced into the environment from these old mining sites comes from the piles of calcines. These sources may be significant source areas if exposed to conducive conditions.

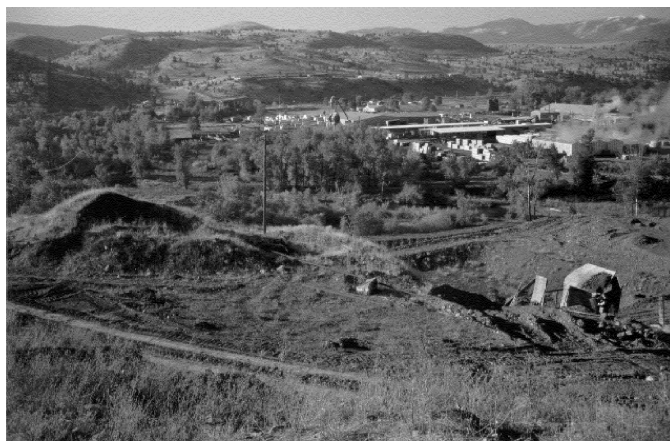
Information on the transport and fate of mercury in the natural environment is important in assessing the risks that are associated with contaminated sites and successfully remediating them. Important factors affecting the transport and fate of mercury include (1) air temperature; (2) humidity; (3) soil and sediment characteristics, including clay and organic content, permeability, and porosity; and (4) type of plants and bacteria present. Elemental mercury may volatilize, move deeper into the subsurface (possibly below the water table), wash into nearby waters, or remain largely inert in the shallow subsurface for years. Once the elemental mercury is oxidized to mercury(II) ions, inorganic and organic (methylmercury) compounds may form. Methylmercury, the most hazardous form of mercury compounds, is a potent neurotoxin and bio-accumulates in animals.

For an understanding of mercury transport and fate, solubility data on elemental mercury and mercury compounds, especially in water, are necessary. One of the potentially most serious environmental issues related to mercury is the chemical dissolution and movement of elemental mercury, mercury ions, and mercury compounds in surface waters and groundwater. Compared to some of the mercury compounds, elemental mercury tends to be relatively insoluble in water. In addition, dissolved mercury tends to be rapidly sorbed by inorganic and organic materials in soils, sediments, and water. These factors can explain why sediments and soils with high levels of elemental mercury can have very low concentrations of dissolved mercury in associated surface waters and groundwater. Although elemental mercury is not as soluble as other forms in water, it can be converted to mercury(II) organic and inorganic forms under certain near-surface conditions of Eh (measure of oxygenating/reducing conditions) and pH. The processing of the mercury ores described above, produced cal-

cines containing mercury in the oxidized state, or the mercury(II) form. Once mercury is in the 2⁺ valence state at or near the surface, it may be further converted into the highly toxic organic mercury(II) compounds (methylmercury) by bacterial assimilation or in some situations by abiotic (chemical) means.

The geology and rock geochemistry of the mercury or gold deposit provides an important control on the composition of mercury mine drainage. Geologic factors such as ore mineralogy, host rock composition, and amount of iron sulfides are essential in determining the pH, metal, and anion concentrations in the mine drainage. In evaluating the possible contamination produced from a site, one needs to look at the mine drainage composition at three different mine environments: (1) water at the point of discharge from the mine workings; (2) water that reacts with calcines; and (3) mine drainage that has mixed with stream water. The composition of the mine drainage must be examined in these three different environments, because the concentration of mercury species in mine drainage and surface waters is strongly affected by atmospheric oxygen, oxygenated stream waters, and reaction with calcines after it is discharged from the mine and thus can be radically different at each location.

It is typical in the geologic settings where mercury and gold deposits are found that sulfate concentrations are high. The sulfate in mine drainage enhances methylation of mercury by promoting sulfide-reducing bacteria in calcines, in mine waste saturated by mine drainage, and where mine waters first mix with stream water. These bacteria act to methylate the oxidized mercury, creating the toxic organic compound. This provides the potential setting in which the deposits can introduce elevated levels of methylmercury into the environment. It must be stressed however, that such a determination can not be made



Reclamation of an abandoned gold mine near John Day in Grant County. Views show conditions before (left) and after (right) reclamation. Many old mines have not yet been reclaimed and made safe and thus still represent sources of contaminants for the environment.

without extensive and detailed sampling at the individual sites, in waters leaving the sites, and in fish from downstream waters.

The Oregon Department of Geology and Mineral Industries (DOGAMI), in cooperation with other agencies, has outlined a reclamation program for abandoned mines. Such a program would have to identify sites to sample and to conduct the detailed sampling and would require several years to complete.

In general, most historic mines have been inventoried and their locations recorded in databases maintained by DOGAMI, the U.S. Geological Survey, the U.S. Bureau of Land Management, and the USDA

Forest Service. These records typically list the primary commodities produced but may not include secondary commodities or methods used to process the ores. However, such information is often available in geologic reports contemporary with the mining operations and in summary publications.

Little to no comprehensive sampling of mine waters and dumps has been performed by any of the participating agencies. In order to identify problem mine sites, an extensive and comprehensive sampling program would need to be instituted, one that focuses not just on total mercury content (which has typically been the practice), but on the vari-

ous forms of mercury.

Cleanup efforts must prioritize sites on the basis of toxicity and proximity to population centers and fisheries. It is probable that many sites do not pose a problem with toxic mercury species, and it may be that any cleanup effort could create problems where they do not exist now. The sites that are near population centers or have the potential to affect fisheries can be quickly identified. Any program to conduct detailed sampling for the various mercury species should be initiated at these sites and focus on the determination of the human component of the contamination. □

Earthquakes and tsunamis documented at southern Oregon coast

Research by California scientists Harvey Kelsey and Eileen Hemphill-Haley of Humboldt State University and Robert C. Witter of William Lettis and Associates, Walnut Creek, has found evidence of 11 large, tsunami-producing earthquakes that occurred off the Pacific Northwest coast in the past 6,000 years.

The research was centered on 28 cores from wetland sediments in an abandoned-meander wetland of the lower Sixes River, just inland from Cape Blanco in southwest Oregon, and the scientists reported on it in the March issue of the Geological

Society of America Bulletin (v. 114, no. 3, p. 298-314).

Ten suddenly submerged wetland soils were identified, covered first with sand and then with tidal mud, documenting abrupt tectonic subsidence of at least 0.5 m and, in some cases, as much as 2.4 m. Supported by other research, such as diatom biostratigraphy, radiocarbon dating, and the discovery of shaking-induced liquefaction features in sand bodies, this evidence points to 10 subduction-zone earthquakes, each of them accompanied by a tsunami that spread sand from the beach as much as 3 km

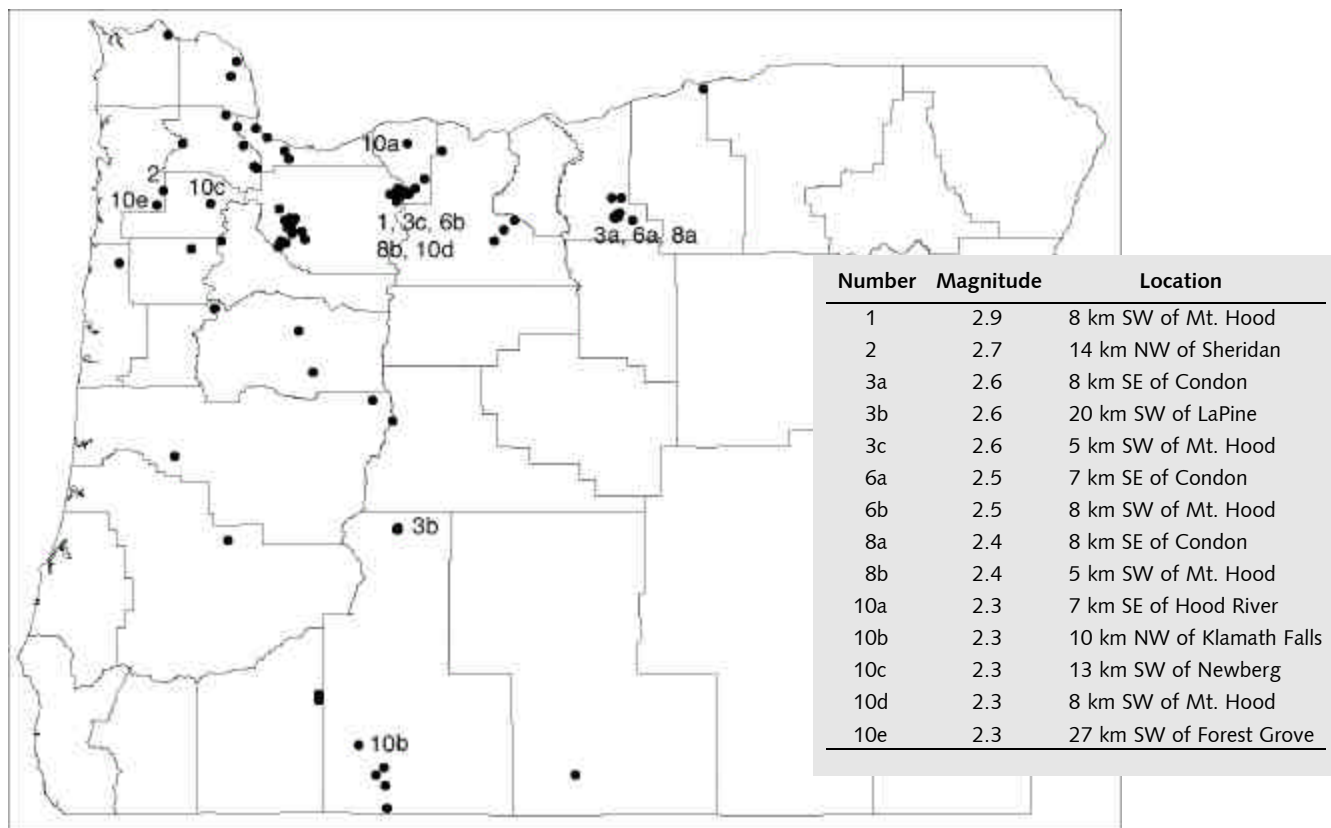
inland. An additional buried soil at the nearby mouth of the Sixes River documents the 11th and youngest earthquake, that of A.D. 1700.

The 11 earthquakes and tsunamis took place roughly between 300 and 5,400 years ago, with an average occurrence interval of about 510 years. Comparison with similar evidence from sites in southwest Washington and the Coos Bay and Coquille River areas suggests that not all these earthquakes ruptured the entire Cascadia Subduction Zone from southern Washington to southern Oregon. □

Oregon seismicity in 2001

These preliminary data have been excerpted from the Quarterly Network Reports on Seismicity of Washington and Oregon, published by the Pacific Northwest Seismograph Network, Department of Earth and Space Sciences, Box 351310, University of Washington, Seattle, WA 98195-1310 (<http://www.ess.washington.edu/SEIS/PNSN/>). They include earthquakes between lat 42.0° and 45.5°N., and long 117° and 125°W.

Earthquakes don't respect geographic boundaries. In 2001, the earthquake most widely felt in Oregon was the February 28 Nisqually earthquake, centered near Olympia, Washington. The deep-seated (52.4 km), magnitude 6.8 event was felt throughout most of Oregon, and as far away as Salt Lake City. The map below shows the earthquakes centered in Oregon in 2001 from magnitude 1 to 2.9. Only a few of these were felt, and no damage was reported. The largest events are summarized in the table insert.



For the year 2001, the earthquakes recorded in Oregon numbered 221, a total of 41 for the first quarter, 38 for the second, 96 for the third, and 46 for the fourth.

The earthquake most widely felt in Oregon was the February 28 Nisqually earthquake, centered near Olympia, Washington. The deep-seated, magnitude 6.8 event was felt throughout most of Oregon and as far away as Salt Lake City. The only Oregon earthquake reported as felt was a relatively small one (magnitude 1.9) on July 22. It was located at about 13 km depth, 21.4 km south-

east of Canby in Clackamas County.

For 27 earthquakes, magnitudes were 2.0 or larger, but none of them exceeded magnitude 2.9.

Two of these earthquakes were located offshore: On May 10, a magnitude 2.6 event was located at a depth of about 31 km, off the coast of southern Curry County. And on September 6, a magnitude 2.9 event was located at a depth of 35 km, off the southern Clatsop County coast.

The Mount Hood region registered several swarms of events. The first began on January 10, 2001, and

continued for most of the month of January. Between January 10 and January 23, 2001, a total of 24 earthquakes were recorded here. The earthquakes were located approximately 5.0–8.0 km south-southeast of Mount Hood at depths ranging from 3.0 to 7.0 km. The magnitudes of the earthquakes ranged from –0.8 to 2.0.

Two more swarms of earthquakes occurred near Mount Hood in late summer. A total of 66 shallow (depths <10 km) earthquakes were located between lat 45° and 45.5°N. and long 121° and 122°W. The first

swarm, 5 km south-southeast of Mount Hood, occurred mainly during August 20, when 9 events were located, none larger than magnitude 1.3, and mostly at depths of <5 km. The second swarm was more vigorous, longer lasting, and slightly deeper (most events 7–9 km deep). It was located in a different area, 8 km south-southwest of Mount Hood, and began on August 21 with very small magnitude (<1) events. Its most intense activity was September 11–16 and included 5 events with magnitude 2.0 or larger and 15 events with magnitude 1.0 or larger. The

largest event was magnitude 2.9 on September 14.

Finally, three earthquakes on December 2 and 3, with magnitudes of 2.1, 2.4, and 2.6, were located about 5 km southwest of Mount Hood. A detailed study of Mount Hood seismicity is underway and will be reported on in a later quarterly.

In the Klamath Falls area, 36 earthquakes occurred, most of them in the second half of the year. Since 1994, most earthquakes in the Klamath Falls area have been considered aftershocks or earthquake activity related to a pair of damaging earth-

quakes in September 1993. The 1993 earthquakes were followed by a vigorous aftershock sequence which decreased over time.

Other notable earthquake activity in Oregon included a magnitude 2.7 earthquake on May 6, located at a depth of 54 km, about 34 km south-east of Tillamook. Events of this depth are unusual in Oregon.

Elsewhere in Oregon, on August 21, a magnitude 1.9 earthquake at about 5 km depth was located near the Three Sisters volcanic area. Earthquakes are uncommon in this region. □

(Thesis Abstracts—continued from page 28)

canism, suggesting a major regional tectonic event.

HLP basalts are variably evolved high-alumina olivine tholeiites. Even primitive basalts are enriched relative to mid-ocean ridge basalts (MORB) in incompatible trace-elements, especially Ba, Sr, and Pb. HLP basalts are isotopically evolved relative to MORB with $^{87}\text{Sr}/^{86}\text{Sr}$ of 0.70305 to 0.70508 and ϵ_{Nd} of +6.7 to +1.6. Isotopic characteristics of Pliocene and Quaternary basalts are more evolved in the east than the west. Miocene basalts are of more uniform isotopic character. Helium isotopes in Quaternary basalts are constant across the HLP with $^3\text{He}/^4\text{He}$ of ~9 RA, reflecting either a strongly depleted MORB source or interaction with a mantle plume.

The HLP and Snake River Plain are linked by divergent trends of silicic volcanism and a belt of Pliocene and younger basaltic volcanism. To explain both provinces I propose the following. At 17 Ma, a small plume head was emplaced under the North American lithosphere, centered near Twin Falls, Idaho, the location predicted by plate-tectonic reconstructions. Basaltic volcanism (Columbia River Basalt Group and Steens Basalt) resulted from emplacement of plume head material under thin lithosphere west of the craton margin and from westward flow from the plume up the lithospheric topography at the craton margin. The latter process may also have driven westward mantle flow under the HLP. Westward migrating volcanism of the HLP may also reflect greater times to incubate crustal magmatism further from the center of the plume head.

Where the lost was found: Geologic sources of artifact raw materials from Lost Dune (35HA792), Harney County, southeastern Oregon, by William H. Lyons (Ph.D., Washington State University, 2001), 258 p.

The prehistoric people who butchered bison in the A.D. 1500s at the Lost Dune archaeological site

(35HA792), Harney County, Oregon, made stone and ceramic artifacts using stone, sand and clay from natural deposits in various places as distant as 300 km. I and collaborators matched attributes and constituents of the artifacts to geologic deposits. Using energy-dispersive X-ray fluorescence spectroscopy, we matched trace-element suites in 92 obsidian artifacts to trace elements characterizing 16 known obsidian sources. Using instrumental neutron activation to measure trace-element suites, we matched 29 artifacts representing 85 percent of chert tools to three of five regional cherts. Using microscopic methods, we matched sand-sized minerals and rock fragments in thin sections of sherds from four of six pots and in eight of ten sandstone artifacts to sand and sandstone deposits in an 80x30-km area extending from Idaho's Owyhee Mountains to the Owyhee River in Oregon. Distributions of the sources of artifacts in an assemblage and the condition of the artifacts may suggest travel, tools system, and economic and social patterns. Artifact sources suggest Lost Dune's bison butchers were at home near the Oregon-Idaho border, where their pottery and sandstone artifacts were made. They may have carried much flaked stone traded from near the Quinn River on the Oregon-Nevada border, including opalite from the Tosawihi quarry complex in north-central Nevada and Massacre Lake/Guano Valley obsidian from northwestern Nevada. They acquired additional obsidian en route to Lost Dune. Distribution in elevation of pottery sources and sites west of the Owyhee Mountains suggest some Intermountain Tradition vessels were made in summer during annual root-digging encampments.

Frequent long-range travel by late-prehistoric pedestrians may have involved bartering for food from others during expeditions. Distances between source areas and the quantity and artifact size of the most distant materials suggest Lost Dune's people carried flaked stone cores and tools for barter. □

Released May 6, 2002:

Tsunami Warning Systems and Procedures: Guidance for Local Officials. Prepared for the National Tsunami Hazard Mitigation Program, by Oregon Emergency Management and the Oregon Department of Geology and Mineral Industries. Special Paper 35, 41 p., CD \$10.

A summary of tsunami warning systems is a new tool to help local governments prepare for tsunamis. Prepared by (OEM) and (DOGAMI), this book describes warning systems and procedures used in various places around the world. Oregon and Washington communities are already taking steps, including developing tsunami evacuation routes, to protect residents and visitors. However, most do not have local warning systems. The information in this book will help cities and counties make cost-effective decisions on implementing new systems.

Released May 6, 2002:

Field guide to geologic processes in Cascadia. Field trips to accompany the 98th annual meeting of the Cordilleran Section of the Geological Society of America, May 13-15, 2002, Corvallis, Oregon, edited by George W. Moore, Oregon State University. Special Paper 36, 324 p., paper (limited supply) \$15, CD \$10.

The guidebook contains the field trip guides for all of the 15 geologic field trips conducted around the GSA section meeting. While the particular focus and the technical level of the individual field trips vary, the guides all provide trip logs that can be used for self-guided tours. Oregon and Washington are sites of very active geologic processes, and the field trips and other reports in this book show examples of dune formation, landslides, mountain building, and soil development. The tours can be introductions to the geology of western and central Oregon, but also to ophiolites in northern California, the Olympic Mountains in Washington, and the scene of one of the largest landslide disasters in Kelso, Washington. Most of the stops are on public land and highways, but some stops are on private property and special permission may be required.

Released June 27, 2002:

Tsunami hazard map of the Coos Bay area, Coos County, Oregon, by G.R. Priest, J.C. Allan, E.P. Meyers III, A.M. Baptista, and R.A. Kamphaus. Interpretive Map Series IMS-21, CD \$10, paper \$15.

The new tsunami hazard map of the Coos Bay area includes Coos Bay, Charleston, North Bend, and beachfront from approximately Snag Lake south to Agate Beach. It is the latest in a series of tsunami maps and studies by Oregon Department of Geology and Mineral Industries (DOGAMI) to help coastal communities pre-

pare for this natural hazard. The last deaths in Oregon from tsunami waves occurred in 1964, when four children were swept out to sea from Beverly Beach. Since then, tsunami hazard maps, evacuation maps, educational materials for school children, road signs, and other products have been developed by a combination of state, local, and federal agencies in cooperation with nonprofit groups and private businesses.

Flooding zones for four potential tsunami levels are shown on the map. Knowing areas that are likely to flood in a tsunami can help communities plan for these events and minimize the damage caused by them.

IMS-21 was prepared by George Priest and Jonathan Allan of the Oregon Department of Geology and Mineral Industries (DOGAMI) from numerical simulations by Edward Myers and Antonio Baptista of the Oregon Graduate Institute of Science and Technology and Robert Kamphaus of the Center for Tsunami Inundation Mapping, a National Oceanic and Atmospheric Administration (NOAA) agency.

Released August 6, 2002:

Geology of the surface and subsurface of the southern Grande Ronde Valley and lower Catherine Creek drainage, Union County, Oregon. A preliminary release, by Mark L. Ferns, Ian P. Madin, and Vicki S. McConnell, Oregon Department of Geology and Mineral Industries, and J.J. Johnson, U.S. Geological Survey, Hawaiian Volcano Observatory. Open-File Report O-02-02, CD \$10.

This report includes a detailed map of the surface geology, two generalized maps of subsurface geologic units, geophysical data, and geochemical data. It also includes, based on well logs, geophysical data, and surface exposures, a descriptive interpretation of hydrogeologic characteristics of the different rock units in the valley.

Declining populations of salmon and steelhead in the Columbia Basin have led to many attempts to improve habitat in spawning streams. The Grande Ronde River in eastern Oregon is one of the few remaining free-flowing tributaries of the Columbia River. Catherine Creek, a major tributary of the Grande Ronde, provides some of the best remaining upland spawning habitat in the system. Low summer flows in the lower reaches of Catherine Creek may impede spawning; therefore considerable interest focuses on enhancing low flows in this creek. One possible solution is to use groundwater instead of surface water for irrigation purposes. This requires a basic understanding of the geology of groundwater resources in the area.

As a critical first step toward evaluating such a proposal, this report was commissioned by the Grande Ronde Model Watershed Board. DOGAMI has now been charged with producing and formally publishing a

Continued on page 35, DOGAMI Publications

For those who do not have the time or opportunity . . .

Geologic notes — Gleanings from recent publications that may be of interest

by Lou Clark and Clark Nieuwendorp, Oregon Department of Geology and Mineral Industries

Contributions by coastal section staff member

Jonathan Allan

"Wave climate change and coastal erosion in the US Pacific Northwest," by Jonathan C. Allan and Paul D. Komar, Proceedings of the Fourth International Symposium on Ocean Wave Measurement and Analysis, WAVES 2001: San Francisco, Calif., American Society of Civil Engineers, p. 680-690.

Abstract: Wave-buoy data collected off the coast of the US Pacific Northwest (Washington and Oregon) document that significant wave heights and periods have progressively increased during recent decades. The average deep-water significant wave heights during the "winter" (October through March) have increased at a rate 0.032 m/yr from 1978 through 2001, a 0.77-m change, while the increase in wave heights associated with the strongest storms has been even greater. Calculated swash runup levels on beaches, which depend on both deep-water wave heights and periods, show parallel increases; the rate of increase has been 0.010 m/yr, which would have produced more than a 6-m landward shift in the mean shoreline during the winter since the late 1970's. Such decadal trends, together with extreme-value analyses of deep-water wave parameters and swash runup levels, are being used to assess the potential for future beach and property erosion along the Pacific Northwest coast.

"Extreme storms on the Pacific Northwest Coast during the 1997-98 El Niño and 1998-99 La Niña," by Jonathan C. Allan and Paul D. Komar: Journal of Coastal Research, v. 18, no. 1 (2002), p. 175-193.

Abstract: Six major storms occurred between 1997 and 2000 offshore from the Pacific Northwest (PNW) of the United States, each generating deep-water significant wave heights greater than 10 m, the approximate height of the 100-year storm event determined from

wave data collected up through 1996. Part of this apparent sudden increase in storm-wave heights was found to be associated with a progressive increase that has spanned the past 25 years (ALLAN and KOMAR, 2000), and a progressive increase in the magnitude and frequency of North Pacific cyclones since the late 1940s (GRAHAM and DIAZ, 2001), but also may have been affected by successive occurrences of a strong El Niño (1997-98) and moderate La Niña (1998-99). The objective of this paper is to document in detail the meteorological conditions and wave generation of these recent storms, due to their unusual strengths and because they produced substantial erosion along the coast. The paper focuses primarily on the two severest storms that crossed the PNW coast; the 19-20 November 1997 El Niño storm that generated 10.5 m significant wave heights, and a storm on 2-3 March 1999 (La Niña) that produced 14.1 m significant wave heights. With the presence of several NDBC buoys close offshore, the movement of each storm can be followed as it developed, and there is good spatial documentation of the meteorological conditions and generated waves. The measured wave heights and periods are used to calculate the along-coast variations in wave runup on PNW beaches. In addition, tide gauges permit analyses of the accompanying storm surge produced by the high winds and low atmospheric pressures of the storms. The largest storm surge occurred during the strongest storm in March 1999, which produced a peak surge of 0.6 m along the Oregon coast and 1.6 m on the Washington coast. Important to the resulting coastal erosion are analyses undertaken of the total water levels reached during the storms, produced by the wave runup above and beyond the elevated tides. Analyses of the 19-20 November 1997 El Niño storm and 2-3 March 1999 La Niña storm yielded estimated wave

Continued on page 36

DOGAMI Publications, continued from page 34

more comprehensive report describing the geology, geologic resources, and geologic history of the entire upper Grande Ronde River basin, including the area covered by this present report. The data released here will be used in the production of the more comprehensive study and thus eventually become available in a more formal version.

A detailed look at this project can be found in the Winter/Spring 2002 issue of Cascadia—the department's quarterly newsletter—at <http://www.OregonGeology.com>.

All publications are available from the Nature of the Northwest Information Center, 800 NE Oregon Street #5, Portland, Oregon 97232. You may also call (503) 872-2750 or order online at <http://www.naturenw.org>. Additionally, these items as well as all department publications can be purchased at DOGAMI field offices including 5375 Monument Drive, Grants Pass, (541) 476-2496 and 1510 Campbell Street, Baker City, (541) 523-3133. □

runup elevations that ranged from 2.8 to 4.1 m, while the total water levels (wave runup plus tides) reached 6.4 m relative to the NGVD 1929 vertical datum. These high water levels were a major cause of extreme erosion observed along the coasts of Oregon and Washington.

Geological Society of America Bulletin, January

"Ages of the Steens and Columbia River flood basalts and their relationship to extension-related calc-alkalic volcanism in eastern Oregon"

Using stratigraphic and chemical correlations and age determinations, researchers have concluded that the Steens Basalt in southeast Oregon represents the first flows in the Columbia River flood-basalt province. Eruption of the Steens Basalt coincides with the emergence of the Yellowstone hotspot at 16.6 Ma. The researchers suggest that the eruptions of the flood-basalt then moved 300 km farther to the north on the Columbia River Plateau where 90% of the eruption of the Columbia River Basalt Group took place.

February

"Location, structure, and seismicity of the Seattle fault zone, Washington: Evidence from aeromagnetic anomalies, geologic mapping, and seismic-reflection data" New, high-resolution aeromagnetic data has been used to characterize the location, length, and geometry of the Seattle fault zone along the entire southern margin of the Seattle basin. The aeromagnetic and geologic data revealed three, near-surface fault strands in the Seattle fault zone that are associated with shallow crustal seismicity and the region of uplift produced by the M 7 Seattle earthquake of A.D. 900-930. It is important to understand the geometry of fault zones in order to evaluate models of crustal deformation and estimate earthquake hazards.

"Effect of the northward-migrating Mendocino triple junction on the Eel River forearc basin, California: Stratigraphic development"

In this paper, the researchers described the use of multi-channel seismic profiles to examine the influence of the Mendocino triple junction on and development of the Eel River forearc basin, northern California, over the past ~5 million years.

March

"Plate-boundary earthquakes and tsunamis of the past 5000 yr. Sixes River estuary, southern Oregon"

Evidence for 11 plate-boundary earthquakes each accompanied by a tsunami has been recorded in coastal wetland sediments in the lower Sixes River valley, southern Oregon. The researchers calculated that the average recurrence interval for plate-boundary earthquakes at the Sixes River valley is ~480-535 yr. Their research was

also able to determine that the number and timing of recorded plate-boundary earthquakes are not the same at different sites along the coast of southern Oregon and southwest Washington.

Geology, February

"Constraints on the preeruptive volatile concentrations in the Columbia River flood basalts"

There is a problem with an evolved, iron-rich and dense basaltic melt ascending so rapidly and voluminously through relative buoyant, continental crust. To account for the volume of Columbia River flood basalt that was erupted, volatiles may have played an important role in reducing the bulk magma density. The researchers concluded that a high concentration of $H_2O + CO_2$ (>4 weight percent) would be required for a buoyant ascent of the Columbia River magmas.

April

"Shallow-crustal magma chamber beneath the axial high of the Coaxial segment of Juan de Fuca Ridge at the source site of the 1993 eruption"

In 1993, a dike propagated from a bathymetric high near the southern end of the Coaxial segment of the spreading Juan de Fuca Ridge. Seismic imaging revealed that a shallow crustal magma chamber was the source for the eruption. The researchers believe that the imagery shows that the chamber is distinct form, and unconnected to the nearby Axial magma chamber. The lack of connectivity suggests that narrow (<5-10 km) conduits transported magma through the upper mantle and lower crust.

Geotimes, December

"Sea level today and tomorrow"

Scientists and policymakers gathered in the lecture hall of the National Academy of Sciences to discuss the prevailing factors causing sea level rise and a coastal disaster. Debate continues over the various factors possibly causing sea level rise, but it is clear that global warming of the Earth's oceans and subsequent thermal expansion is a contributor to sea-level rise.

Science, January 11

"Where's the Map?"

If you need to see a catalog that lists nearly every map the U.S. Geological Survey has produced and many maps others have published (state governments, universities, private companies, and organizations), then go to the Website for the National Geologic Map Database. The database can be found at the following URL: <http://ngmdb.usgs.gov>. At this Website, you'll also find links to other databases, such as GEOLEX, a database of geological formations and their attributes.

"Of Ocean Weather and Volcanoes: Oregon's Bulging Unabated"

Scientists at the U.S. Geological Survey's Cascades Volcano Observatory are anxious to learn if Central Oregon's Three Sisters volcanoes are about to awaken. Magma has risen into a chamber a few kilometers below the surface just west of the volcanoes. The new magma has caused a 15 kilometer-wide bulge that is rising about 30 millimeters per year. Instruments are monitoring the bulge for any signs that the magma is beginning to punch its way up through the overlying crust.

January 18

"Follow the Money"

You can now follow the money for industrial research and development at the National Science Foundation's Website (www.nsf.gov/sbe/srs/iris/start.htm). The site hosts a database that contains information collected between 1953 and 1998 on such things as R&D by state and industry, by scientific field, by number of companies, and R&D expenditures per scientist or engineer.

"Science, Terrorism, and Natural Disasters"

After the September 11 terror attacks, the U.S. National Academy of Science established a committee to look into the vulnerability of our infrastructure and find ways in which science could be used to help mitigate the consequences of a future attack. Science can play a role in recovery and repair if we look at natural disasters and terror attacks jointly. If you think about it, the two have the similar consequences.

February 15

"To Make Grow"

"To make grow" is the local translation of Mount Pinatubo, a volcano on the Luzon Island, Philippines. Ten years after the volcano erupted it's true to its name. The local Philippine people have built new towns, industries, and farms to replace those that were destroyed. The eruption also helped the science of volcanology grow. Geologists gained scientific insights into pre-eruption events and guidelines for issuing life-saving warnings.

February 22

"Working Up to the Next One"

In southern California, two geophysicists are studying the seismic cycle of heightened seismicity before large earthquakes. The geophysicists are trying to determine if the seismicity of faults breaking in moderate earthquake is chatter or a readable seismic code that's giving a warning of the larger quake to come. Their work is adding insight into the physics of fault mechanics and a step towards recognizing faults that are about to rupture.

March 29

"Deep Quakes Slow But Very Steady"

Scientists are puzzled by the occurrence of strange temblors deep under the Pacific Northwest, called a slow earthquake. The temblors go off silently about every 14 months and the scientists aren't sure why the earthquakes adhere to a regular schedule. The scientists are looking into the possibility that the slow earthquakes may be a precursor to a major event. If confirmed, it is a major step toward predicting earthquakes and understanding how plate boundaries work.

"The Study of Superfloods"

What formed the immense channels on Mars? Could there be a connection to the super flood-eroded landscapes on Earth? Repeated out-bursts of the ice-dammed Glacial Lake Missoula created the spectacular Channeled Scabland region in Washington state. These huge glacial water influxes probably influenced the ocean circulation and climate at the end of last ice age. So, did the super floods carve-out the channels on Mars?

April 5

"Breaking Through the Crust"

How many volcanic eruptions are there between eastern Oregon and western Wyoming? Would you be surprised to find out that 142 volcanic eruptions have been recorded? These eruptions started 16 million years ago with the formation of the Yellowstone hotspot. The hotspot has been on an easterly track and is now under the Yellowstone Plateau, which has been the focus of the largest known volcanic eruptions during the past several million years. The hotspot is still active.

April 19

"Osmium Remembers"

Researchers believe that the wide range of osmium isotopic composition in grains weathered from bodies of mantle rocks now exposed in the crust of Oregon and Northern California records a "core signal." This "core signal" is a recording of the chemical crystallization of the Earth's inner core. The recording was transferred to the outer core and again to the mantle when portions of the two mixed. The researchers interpreted the "core signal" in the grains to mean that a solid, inner core formed within 250 million years of Earth's formation and a dipole magnetic field was established by convection in the outer core early on.

Science News, December 1

"Tough Choices: Endangered species are keeping some landowners thirsty"

The West is thirsty for water and its thirst is more than the water available. A western basin that underscores

the shortage of water and complications related to water-rights is the Klamath Basin in Oregon. Federal agencies, landowners, tribal communities, and protectors of the environment have "tough choices" to make over the issue of entitlements to water and protection of endangered species. In the meantime, farmers in the Klamath Basin are suing the federal government for economic damages as a result of the government withholding water from the rights holders to protect fish.

January 12

"Satellites could help track sea level"

A GPS receiver on the edge of Central Oregon's Crater Lake records the test signals coming straight from Earth-orbiting satellites and those that bounced off the calm waters of the lake. NASA scientists are hoping their tests will pave the way for a quick and inexpensive way to use GPS to monitor global sea level change.

February 23

"Shuttle yields detailed 3-D atlas"

Instruments on board the space shuttle Endeavour collected new radar measurements that will be used to make a new generation of topographic map for the United States and worldwide. The new topographic point data is spaced about 90 m apart, and according to NASA's Jet Propulsion Laboratory, charts made with the new data will be better than any in use today.

Nature, January 24

"Making waves on rocky ground"

In the January 24, 2002, issue of *Nature* there is a book review of Edward Bryant's *Tsunami: The Underrated Hazard*. According to the reviewer, the book provides a wide-ranging review of tsunamis, especially interesting are the descriptions of past tsunamis. However, the book falls short of being "...an authoritative, multipurpose textbook for newcomers to tsunami research" but the book makes a useful reference source.

January 31

"The investment forecast"

The authors analyzed 80-year projections from 19 different global-climate models and included interactions between the oceans and the atmosphere. They also applied, which is a different approach, probabilistic techniques used in short- and medium-range weather forecasting to a large multi-model ensemble in a climate-change context to assess the frequency of extreme events. In other words, forecasters are getting closer to providing policy-makers with a reliable way to make better use of climate-change models and risk assessment of extreme events. As an example of extreme rainfall and severe flooding, the article shows a picture of the 1996 flooding in Oregon City, Oregon.

March 7

"Amazing grace"

A couple of months ago NASA and DLR, Germany's aerospace agency, launched twin satellites (GRACE; Gravity Recovery and Climate Experiment) into low Earth orbit in order to accurately measure the Earth's gravitational pull. Scientists are expecting the results of the gravity measurements to reveal new information about the Earth's geology and hydrology. Also, climate researchers are hoping to obtain better measurements of sea level and so get at the effects of ocean currents and temperature changes. The mission is expected to last for five years until gravity pulls the satellites back to earth. In the meantime, a new planetary gravity map will be constructed every 30 days giving scientist a chance to see how the Earth's gravity changes over time.

April 11

"The disappearing dipole"

The Earth's main dipole field has been declining over the past 150 years and could disappear early in the next millennium. That's what measurements of the Earth's magnetic field are telling researchers. What does this mean for a compass needle? The researchers suggest that our planet's magnetic polarity could be in the early stages of reversal.

April 18

"The 20-year forecast"

The 20-year forecast of climate change provides policy-makers with information for planning and implementing strategies to mitigate or adapt to climate change over a range of likely outcomes. Two papers in this issue address uncertainty in climate change projections from a probabilistic approach by including estimates of the likely range of future warming that are consistent with observed twentieth-century change. Both sets of authors agree that the upper bound on potential global warming for 2100 may well be above previous predictions. □

EDITOR'S CORNER

Reminders and news

October 13–19 will be **Earth Science Week**. Check how you can be involved in your community. The official theme of this year's activities is water, under the heading "Water Is All Around You." Find much relevant information on the internet under <http://www.earthsciweek.org>.

In the next "Editor's Corner," the editor will have a different name. The current editor, initiated into the secrets of producing *Oregon Geology* 23 years ago by Beverly Vogt—at a time when the producing was done with typesetting, galley proofs, and pasting—**now retires**, with thanks to all the readers and contributors and deep sympathy to all who had to suffer from my mistakes.—KN

Highlighting Recent Publications

Now available from The Nature of the Northwest Information Center

Two new nature guides to the Northwest

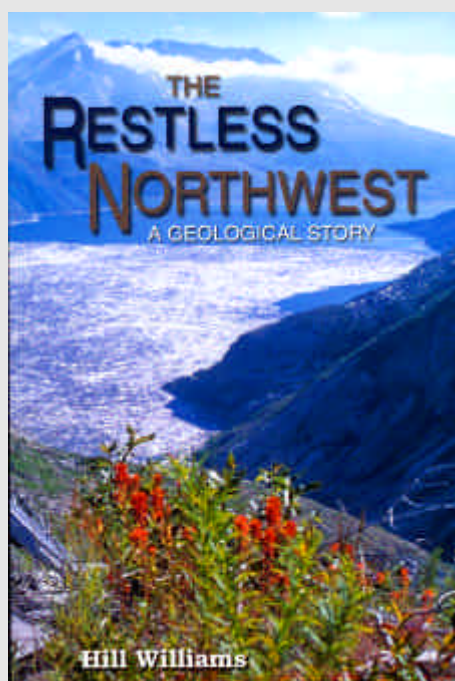
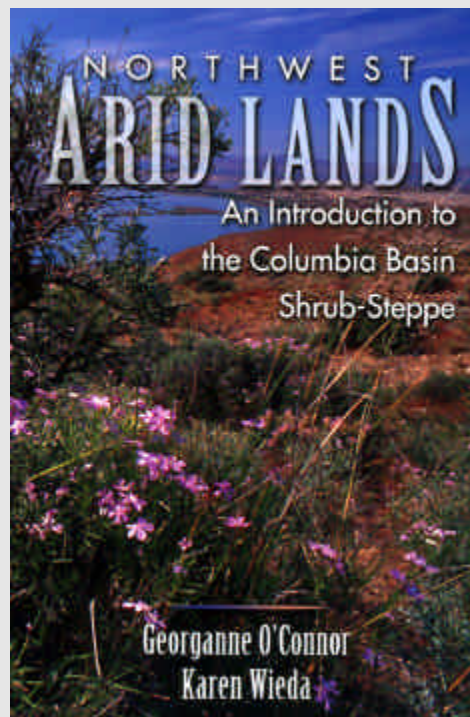
Northwest Arid Lands. An Introduction to the Columbia Basin Shrub-Steppe, by Georganne O'Connor and Karen Wieda. Columbus, Ohio, Battelle Press, 2001. 218 p., \$18.95.

Awareness and basic knowledge are the main aims of this nature book, centering on the Tri-Cities in southeastern Washington and encompassing the arid south of the Columbia Basin ecoregion that extends into northern Oregon between the Blue Mountains and the Cascade Range.

Ecologists call this a shrub-steppe. From its most common shrub it is known as sagebrush country. Sometimes it is just called cold desert. While the book is not meant to be a comprehensive guide, it shows how rich and varied life in this region really is. And it shows it at a beginner's level.

The main chapters of the book deal with plants and plant habitats, wildlife from elk to caddisflies, and geology and soils. Most of the liberally illustrated chapters end with discussions of environmental change, listings of species that are cause for special conservation concern, and autobiographical sketches of scientists that are involved in research of the region.

Appendices add a large collection of beautiful plant and animal photos, ecologic and geologic maps, a description of places that can be visited, a glossary of some of the more technical terms, a bibliography, and two field trip guides. □



The Restless Northwest. A Geological Story, by Hill Williams. Pullman, Wash., Washington State University Press, 2002. 163 p., \$19.95.

The author was a science writer for the Seattle Times for 24 years. The patience it took to put this book together he credits to the scientists he interviewed and accompanied in their work. They patiently explained their business to him who had no formal science background. "I always figured if I could get something through my head, I could do a better job of telling it to other nonscientists," he confesses. He did, and you'll want to read his "Story" from cover to cover.

Part I of the "Story" deals with the distant geologic past of this section on the surface of our globe and the movements of the Earth's crust that eventually created the continental basis of the Pacific Northwest. Part II begins about 50 million years ago and describes what happened to that basis to shape the land we know today. Frequent sidebar texts focus on specific questions or illustrative examples. The book concludes with a geological almanac, a glossary of geologic terms, and an index. □

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Publication of *Oregon Geology* will continue!

Budget cutbacks and changing technology require that we make changes to the magazine, but we are fully committed to keeping it alive.

Over the timespan of (so far) sixty-four years, the appearance, the subject emphasis, even the name have undergone changes, reflecting the changes of the times in which we live, the changes of the Department's role in them, and the changes of the role of the earth sciences for the welfare of Oregon. What has not changed is the need for the services the magazine has provided—and will not stop providing.

We are now implementing another major change—we hope it will be the last one for a while: Increased demand for the talents of our staff editor, and a reduction in resources mean that we can no longer publish four edited issues a year. One possibility was that we would have to stop production of *Oregon Geology*, which we are not willing to do. Instead, we will now publish two issues a year as a journal on our website.

We will also predominantly compile rather than extensively edit the material submitted. Consequently, we are now asking that material be submitted to us in production-ready quality. For details and the new publication schedule, see "Information for Contributors" below.

We believe *Oregon Geology* is an important publication, offering a unique and suitable place to share information about Oregon that is useful for the geoscience community and ultimately for all Oregonians. Please help us by continuing to read the journal *Oregon Geology* and submit articles.

Information for Contributors

Oregon Geology is designed to reach a wide spectrum of readers in the geoscience community who are interested in all aspects of the geology of Oregon and its applications. Informative papers and notes, particularly research results are welcome, as are letters or notes in response to materials published in the journal.

Two copies of the manuscript should be submitted, one paper copy and one digital copy. While the paper copy should document the author's intent as to unified layout and appearance, all digital elements of the manuscript, such as text, figures, and tables should be submitted as separate files. Hard-copy graphics should be camera ready; photographs should be glossies. Figure captions should be placed together at the end of the text.

Style is generally that of U.S. Geological Survey publications. (See USGS *Suggestions to Authors*, 7th ed., 1991, or recent issues of *Oregon Geology*.) References are limited to those cited. Pre-submission reviewers should be included in the acknowledgments. In view of increasing restrictions on editing time, adherence to such style will be required more strictly than in the past.

For the foreseeable future and beginning with volume 64 for the year 2002, *Oregon Geology* will be published twice annually on the Department web site <http://www.oregongeology.com>, a spring issue on or shortly after March 15 and a fall issue on or shortly after October 1. Deadline for submission of scientific or technical articles will be January 31 and August 15, respectively. Such papers will be subjected to outside reviews as the Department will see appropriate.

Conclusions and opinions presented in articles are those of the authors and are not necessarily endorsed by the Oregon Department of Geology and Mineral Industries.

Authors will receive a complimentary CD with a PDF version of the issue containing their contribution.

Manuscripts, letters, notices, and photographs should be sent to Klaus Neuendorf, Editor, *Oregon Geology*, 800 NE Oregon Street, Portland, OR 97232-2162, e-mail contact klaus.neuendorf@dogami.state.or.us.

Please send us your photos

Since we have started printing color pictures in *Oregon Geology*, we are finding ourselves woefully short of good color photographs showing geologic motifs in Oregon. That is why we invite your contributions.

Good glossy prints or transparencies will be the best "hard copy," while digital versions are best in TIFF or EPS format, on the PC or Mac platform.

If you have any photos you would like to share with other readers, please send them to us (Editor, *Oregon Geology*, 800 NE Oregon Street, Portland, OR 97232-2162, # 28; e-mail klaus.neuendorf@dogami.state.or.us.) with information for a caption. If they are used, publication and credit to you is all the compensation we can offer. If you wish to have us return your materials, please include a self-addressed envelope.

Places to see—Recommended by the Oregon Department of Geology and Mineral Industries:

Lava River Cave, properly called a lava tube, whose side walls show the marks of the basalt lava that continued to flow, while its outside was cooling and turning into hard rock. Entrance to the tube became possible after a portion of its ceiling collapsed. The beginnings of the flow extend back to the nearby Newberry shield volcano which produced a great variety of volcanic attractions, including cinder cones, pumice cones, lava and obsidian flows, Lava Cast Forest, caves, lakes, streams, and waterfalls. Many of the Newberry basalt flows are less than 10,000 years old and retain the fragile surficial features that are characteristic of freshly erupted lava. The youngest ones have little or no vegetation and a stark moonscape appearance which was used for astronaut training in 1966. The whole area is now part of the Newberry National Volcanic Monument, managed by the USDA Forest Service.

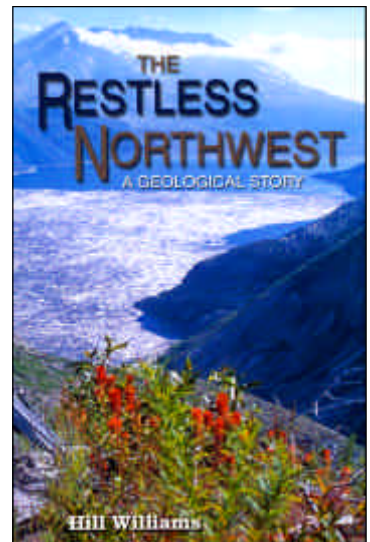
Access: From U.S. Highway 97 between La Pine and Bend. The one-mile Lava River Cave has an entrance station, and lanterns are available for rent. The cave temperature is a constant 42°, so wear warm clothing. For the protection of hibernating bats, this cave is closed from November 1 through April 15. During the summer 2002 season, the cave is open (always 9:00 am to 5:00 pm) as follows: May 1 to June 9—open Wednesday through Sunday; June 12 to September 2—open daily; September 4 to October 19—open Wednesday through Sunday. For more detail information, visit the Lava Lands Visitor Center, on Highway 97, 13 mi south of Bend, phone (541) 593-2421, or the internet at <http://www.fs.fed.us/r6/centraloregon/recinfo/dayuse/lavariver.html>.

(Oregon Department of Transportation photo no. 4177)

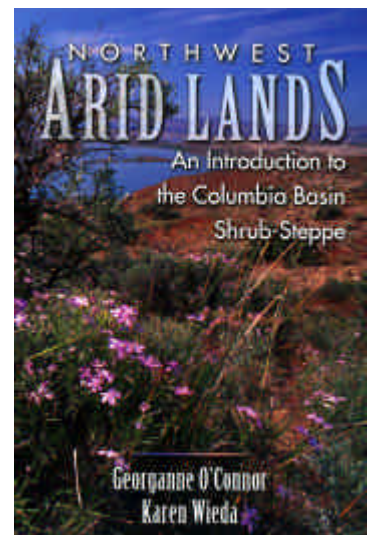




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