Hettangian and Sinemurian Ammonoid Zonation for the Western Cordillera of North America

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Hettangian and Sinemurian Ammonoid Zonation for the Western Cordillera of North America[1]

by

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Abstract.–TAYLOR D.G., GUEX J. and RAKUS M., 2001. Hettangian and Sinemurian Ammonoid Zonation for the Western Cordillera of North America. *Bull. Soc. vaud. Sc. nat. 87.4*: 381-421.
Eighteen Zones and seven ammonite Subzones are recognized for the Hettangian and Sinemurian stages in the Western Cordillera (North America). All except the Canadensis Zone are described as new. The sequence is based primarily on sections from the Graylock Formation in Oregon and the Sunrise Formation in Nevada, while relevant sections from Mexico and British Columbia are referred to the succession. The Spelae Zone through the Rursicostatum Subzone are allocated to the Hettangian Stage, while the Columbiae Subzone through the Harbledownense Zone are referred to the Sinemurian Stage. One new genus (*Bartoliniceras* gen. n.) and seven new species are defined herein.

Keywords: Ammonites, Zonation, Lower Jurassic, North-America.

Résumé.–TAYLOR D.G., GUEX J. et RAKUS M., 2001. Zonation à Ammonites de l'Hettangien et du Sinémurien de la Cordillère Occidentale de l'Amérique du Nord. *Bull. Soc. vaud. Sc. nat. 87.4*: 381-421.
Dix huit zones et sept sous-zones d'ammonites sont reconnues dans les étages Hettangien et Sinémurien de la Cordillère Occidentale de l'Amérique du Nord. A l'exception de la Zone à Canadensis, toutes ces zones sont nouvelles. La séquence est principalement basée sur les sections des Formations Greylock dans l'Oregon et Sunrise dans le Nevada. Les séries stratigraphiques du Lias inférieur du Mexique et de la

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CODEN: BSVAA6

Colombie Britannique sont également prises en compte. L'intervalle allant de la zone à Spelae jusqu'à la zone à Rursicostatum est assigné à l'Hettangien et celui qui va de la Sous-Zone à Columbiae jusqu'à la Zone à Harbledownense est rattaché au Sinémurien. Un nouveau genre (*Bartoliniceras* gen.n.) et sept nouvelles espèces sont définis ici.

Mots clés: Ammonites, zonation, Jurassique inférieur, Amérique du Nord.

Introduction

This paper provides a formal zonal nomenclature for the Hettangian and Sinemurian stages in the Western Cordillera of northern Mexico, the United States, and British Columbia (Figs. 1 and 2). The finest Hettangian sequences yielding well preserved ammonoids are in the Gabbs Valley Range (NYC) and Garfield Hills (Pamlico) in Central Nevada, while somewhat less complete sequences yielding poorer ammonoids occur in the Queen Charlotte Islands (Tipper and Guex 1994). Hettangian ammonoids are documented from numerous additional localities in Canada (Frebold 1964, Poulton 1991) and Alaska (Imlay 1981). Late Hettangian ammonoids are also documented from Oregon (Taylor 1988, 1998). The references given above concern the principal localities for establishing the zonation. Smith *et al.* (1994) includes information for lesser known Hettangian and Sinemurian localities in the Western Cordillera.

The most complete Triassic-Jurassic transition yielding common ammonoids is at New York Canyon (Guex 1980, 1982, 1995; Taylor *et al.* 2000), which has been proposed as the System boundary stratotype (Taylor *et al.* 1983, Guex *et al.* 1997). Transition beds poor in macrofauna but yielding radiolaria occur in the Queen Charlotte Islands (Tipper *et al.* 1991, 1994).

The Hettangian to Sinemurian transition beds are well exposed in Nevada (Taylor 1996, 1998), British Columbia (Frebold 1967, Smith and Tipper 2000) and Queen Charlotte Islands (Tipper and Guex 1994).

The Sinemurian is well known in Nevada (Taylor *et al.* 1983), British Columbia (Frebold 1967, Tipper *et al.* 1991, Smith and Tipper 2000, Palfy *et al.* 1990, 1994) and Sonora (Gonzales-Leon *et al.* 1996, Taylor *et al.* 1998).

A summary of the faunal sequences in the Western Cordillera established by the above authors as well as new data given herein (Figs. 3-5) provide the basis for the zonation established below. Strongly discontinuous paleontologic records necessarily generate discrete relative biochronologic time-scales. The paleontologic record from the Hettangian studied here, even if relatively complete, is highly discontinuous and the zones defined herein are considered as discrete units, like the Triassic zones defined by Tozer in 1967 (see Tozer *loc. cit.* p. 11).

Figure 1.–Location of the most important Hettangian and Sinemurian Ammonoid localities in western North America.

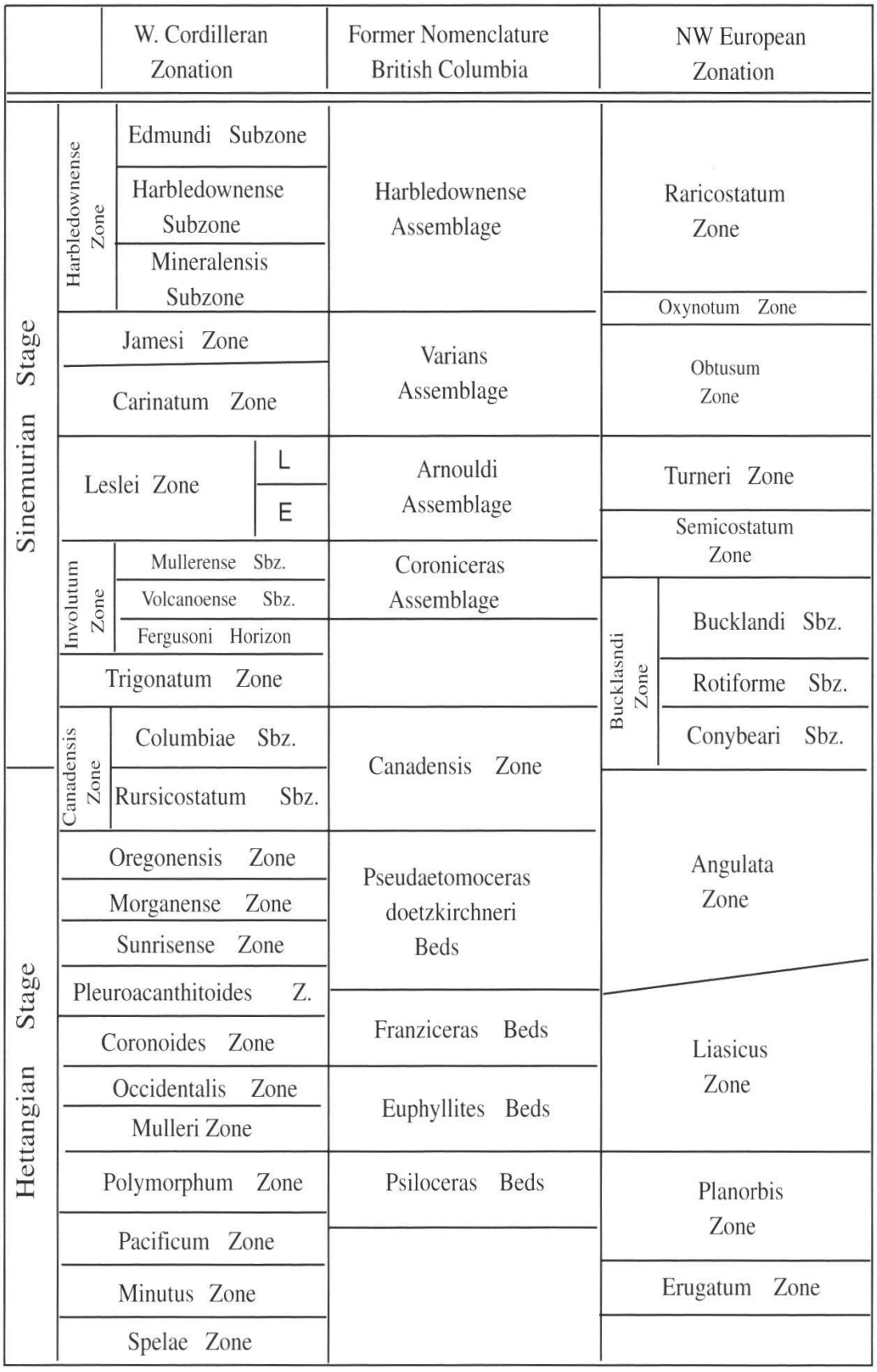


Figure 2.–Zonation for the Hettangian and Sinemurian Stages in Western North America.

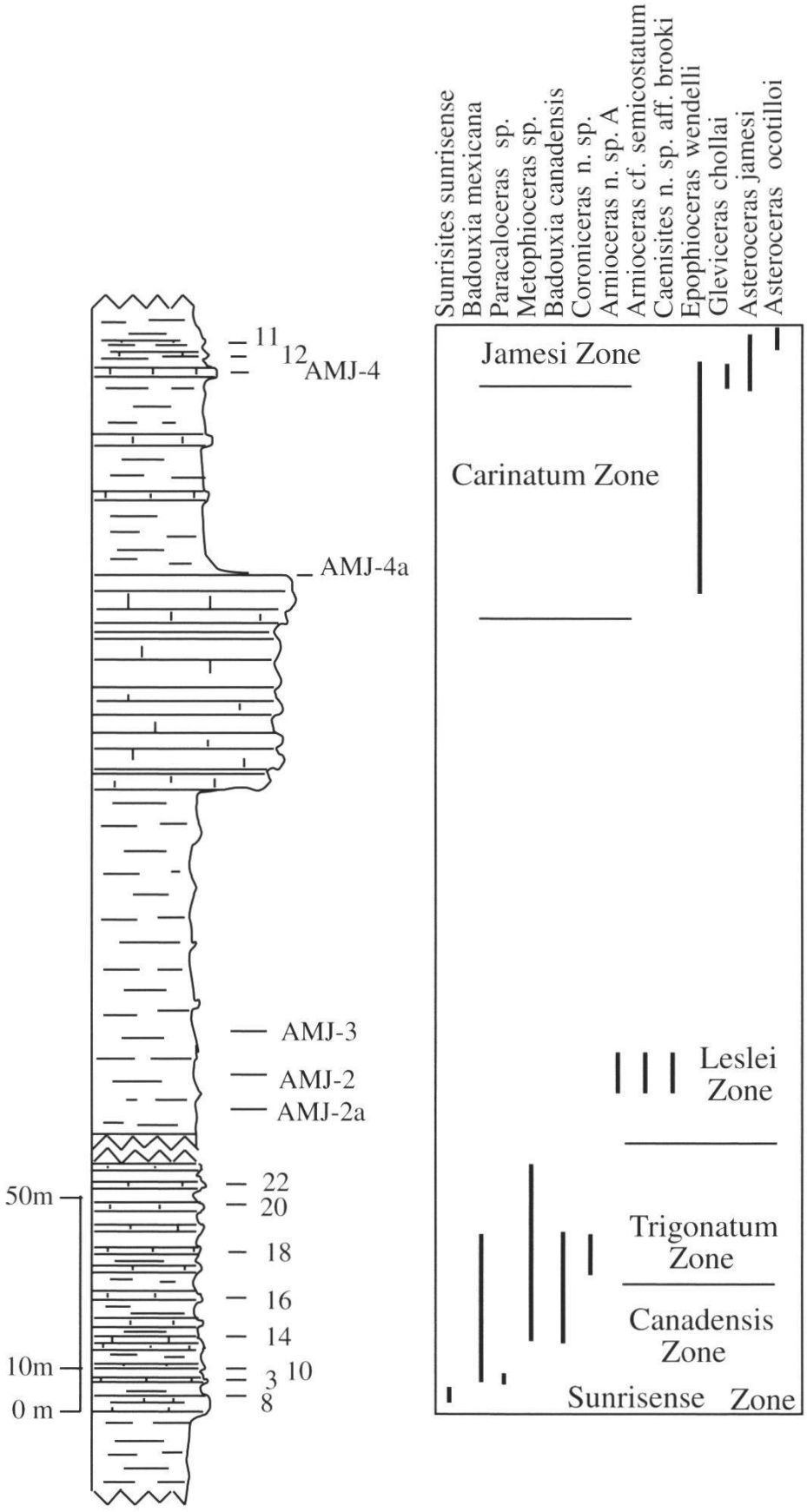


Figure 3.–Stratigraphic section and ammonoid ranges in the Antimonio Formation, Sierra del Alamo, Sonora, Mexico.

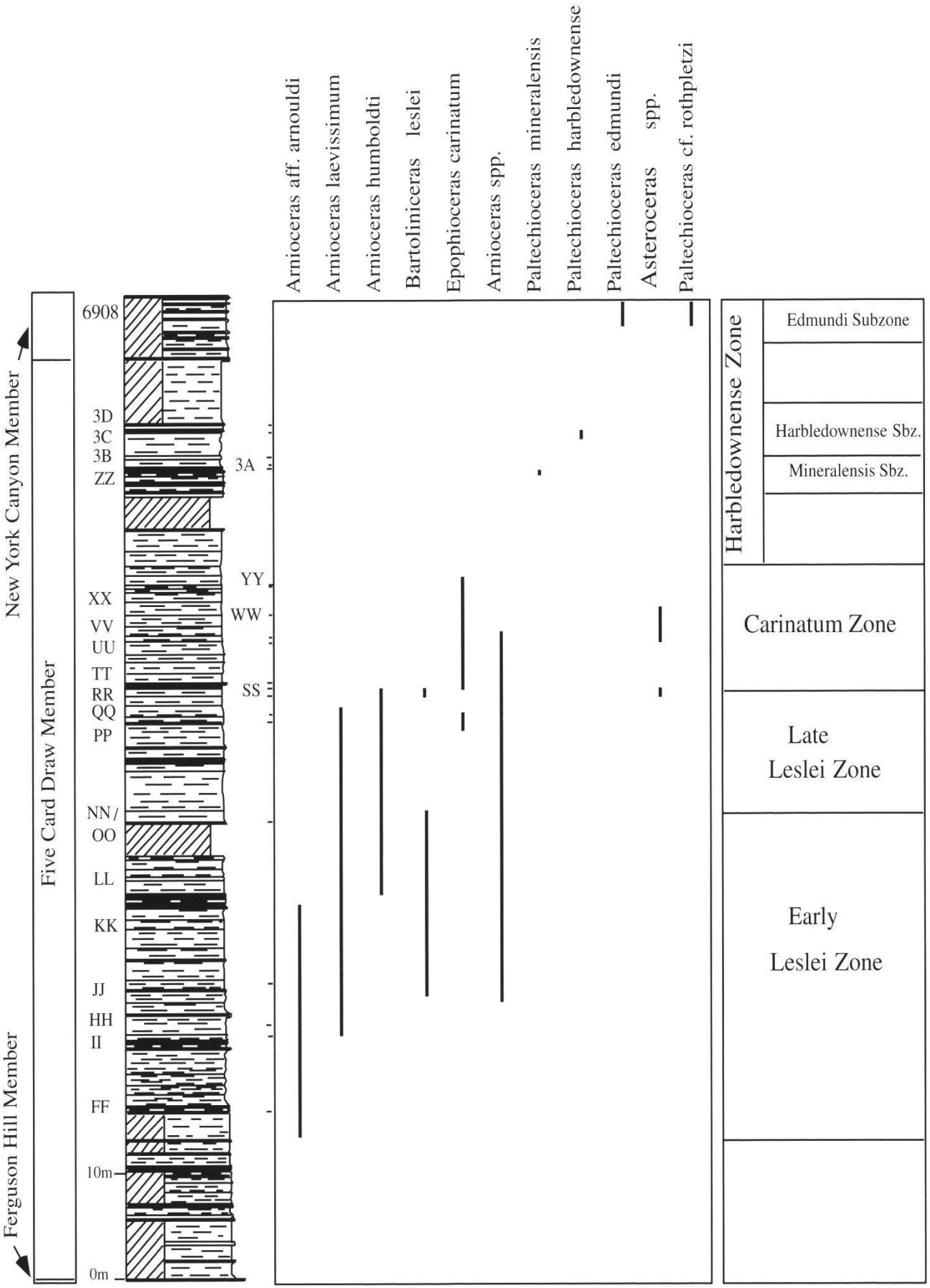


Figure 4.–Stratigraphic section and ammonoid ranges at Five Card Draw, Gabbs Valley Range, Nevada.

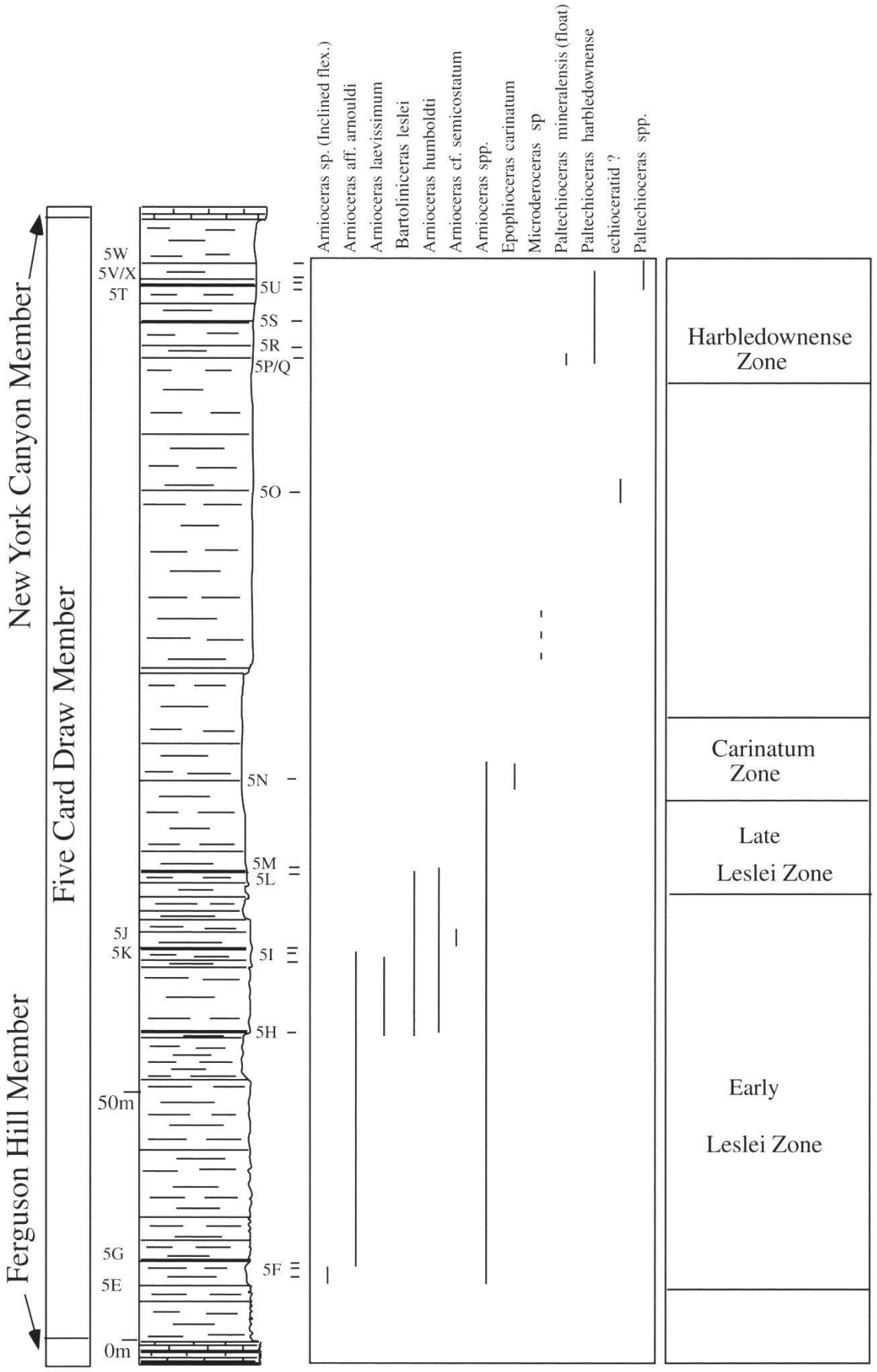


Figure 5.–Stratigraphic section and ammonoid ranges at First Canyon, Shoshone Mountains, Nevada.

The Hettangian Zones (Fig. 6)

Spelae Zone

Name-bearer, *Psiloceras spelae* GUEX, which occurs at Ferguson Hill in New York Canyon, Nevada (Fig. 1; see TAYLOR *et al.* 2000, Fig. 1, Sec. E). *Psiloceras spelae* GUEX is restricted to the zone. *Juraphyllites* sp. is also reported from the interval. The fauna from the Spelae Zone at Ferguson Hill in Nevada (TAYLOR *et al.* 2000, Fig. 3) occurs just 5 m above latest Triassic ammonoids referable to the Crickmayi Zone. A few meters above the Spelae fauna is *Rhacophyllites* followed closely upsection by the Minutus fauna. The horizon chosen for the System boundary is bed 16 (TAYLOR *et al.* 2000, Fig. 3). A reference section in Reno Draw (TAYLOR *et al.* 2000, Fig. 4) can be correlated lithologically. There, only the bivalve *Kalentera* occurs in the interval represented by the Spelae Zone. The Zone is not represented elsewhere in North America.

Minutus Zone

Name-bearer *Choristoceras minutus* GUEX. Type section, New York Canyon at Ferguson Hill (TAYLOR *et al.* 2000, Fig. 3, Section E). The zone there occurs in the upper 2 m of the Muller Canyon Member, or in Beds Z 2-4 of GUEX (1995) and in an equivalent interval at Ferguson Hill. *Choristoceras minutus* GUEX, *P. marcouxi* GUEX and *Odoghertyceras deweveri* GUEX are restricted to the zone. Material referred to *P.* cf. *pacificum* GUEX also occurs in it. Note that *Odoghertyceras*, characteristic of the Minutus Zone, is also known from the base of the Tilmanni Zone sensu HILLEBRANDT (1990, 1994) in South-America.

Pacificum Zone

Name-bearer *Psiloceras pacificum* GUEX. Type section, New York Canyon at Section 1 and beds Z4 and Z5 of GUEX (1995). The zone is characterized by the smooth species *Psiloceras pacificum* below the costate species *P. polymorphum* GUEX. The Pacificum Zone is widespread in New York Canyon and occurs at the base of the Jurassic section as crushed material at Pamlico in the Garfield Hills, Nevada. The *Psiloceras* beds at Kennecott Point, Queen Charlotte Islands (TIPPER and GUEX 1994), are allocated in part to this zone (Fig. 2).

Polymorphum Zone

Name-bearer *Psiloceras polymorphum* GUEX. Type section, New York Canyon at Section 1 of GUEX (1995), beds Z-9 through Z-14 of GUEX (1995). The zone is characterized by abundant *P. polymorphum* and, in its lower part,

by the uppermost occurrences of *P. pacificum* GUEX. *Caloceras crassicostatum* GUEX and *Waehneroceras tenerum* (NEUMAYR) occur at the top of the Zone. The zone is widespread in New York Canyon and is well represented at Pamlico. At Pamlico *Waehneroceras tenerum* and *Psiloceras* have been recovered recently from beds immediately beneath those in which Assemblage B occurs (TAYLOR 1998, Fig. 6). The *Psiloceras* beds at Kennecott Point, Queen Charlotte Islands (TIPPER and GUEX 1994), are allocated in part to this zone.

Mulleri Zone

Name-bearer *Pleuroacanthites mulleri* GUEX. Type section, New York Canyon, Section 1 and beds Z15 through Z20 of GUEX (1995). The zone there is characterized by abundant *Discamphiceras antiquum* GUEX along with early *Pleuroacanthites* and diverse *Kammerkarites*. The zone most probably is represented at Pamlico by Assemblage B (TAYLOR 1998, Fig. 6).

Occidentalis Zone

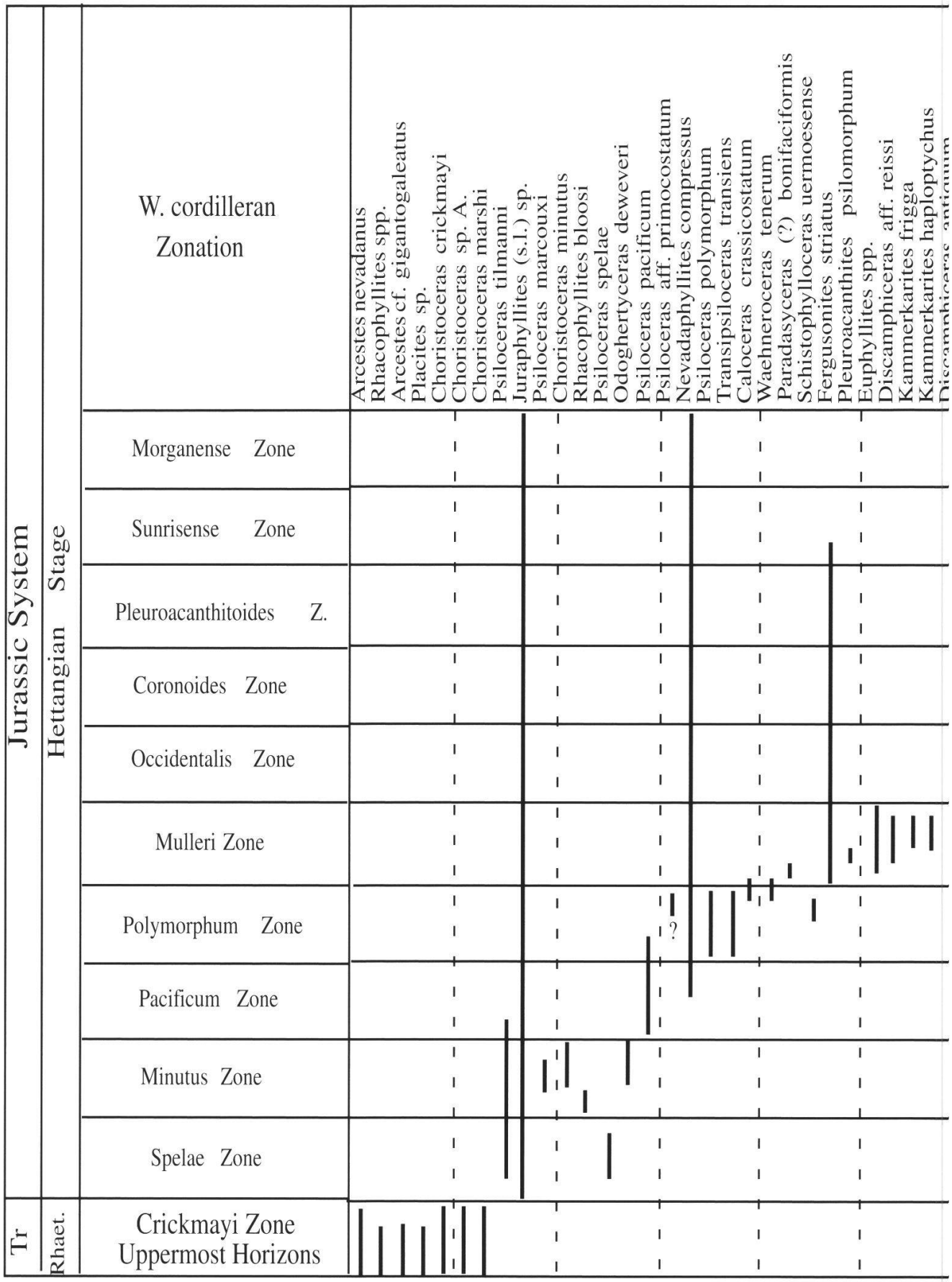
Name-bearer, *Euphyllites occidentalis* GUEX. Type Section, New York Canyon, Section 1 and beds Z24 through Z36 of GUEX (1995). The zone in its type area is characterized by the first appearance of *Discamphiceras silberlingi* GUEX as well as *Euphyllites occidentalis* GUEX and *Kammerkarites diploptychoides* GUEX. At Pamlico the interval yields the former two species along with *Pleuroacanthites* aff. *biformis* (SOWERBY) and *Kammerkarites* n. sp. The *Euphyllites* beds from Kennecott Point (TIPPER and GUEX 1994) are assigned to this zone.

Coronoides Zone

Name-bearer, *Franziceras coronoides* (GUEX). Type section, New York Canyon, Section 1 and beds Z43 through Z64 of GUEX (1995). This zone in its type area is well characterized by the restricted occurrences of *Franziceras coronoides* GUEX, *Franziceras* aff. *ruidum* BUCKMAN, and *Kammerkarites praecoronoides* GUEX. The zone is represented by Assemblage C at Pamlico (TAYLOR 1998, Fig. 6). The lower *Franziceras* beds at Kennecott Point (TIPPER and GUEX 1994) are assigned to this zone.

Pleuroacanthitoides Zone

Name-bearer *Mullerites pleuroacanthitoides* GUEX. Type section, New York Canyon, Section 1 and beds Z67 through Z90 of GUEX (1995). The zone is characterized by the restricted occurrences of *Discamphiceras kammerkaroides* GUEX, *Eolytoceras praecursor* GUEX and *Mullerites pleuroacanthitoides* GUEX. *Discamphiceras submesogenos* GUEX first


Jurassic System
Tr
Hettangian Stage
Rhaet.
W. cordilleran Zonation
Morganense Zone
Sunrisense Zone
Pleuroacanthitoides Z.
Coronoides Zone
Occidentalis Zone
Mulleri Zone
Polymorphum Zone
Pacificum Zone
Minutus Zone
Spelae Zone
Crickmayi Zone Uppermost Horizons
Arcestes nevadanus
Rhacophyllites spp.
Arcestes cf. gigantogaleatus
Placites sp.
Choristoceras crickmayi
Choristoceras sp. A.
Choristoceras marshi
Psiloceras tilmanni
Juraphyllites (s.l.) sp.
Psiloceras marcouxi
Choristoceras minutus
Rhacophyllites bloosi
Psiloceras spelae
Odoghertyceras deweveri
Psiloceras pacificum
Psiloceras aff. primocostatum
Nevadaphyllites compressus
Psiloceras polymorphum
Transipsiloceras transiens
Caloceras crassicostatum
Waehneroceras tenerum
Paradasyceras (?) bonifaciformis
Schistophylloceras uermoesense
Fergusonites striatus
Pleuroacanthites psilomorphum
Euphyllites spp.
Discamphiceras aff. reissi
Kammerkarites frigga
Kammerkarites haploptychus
?

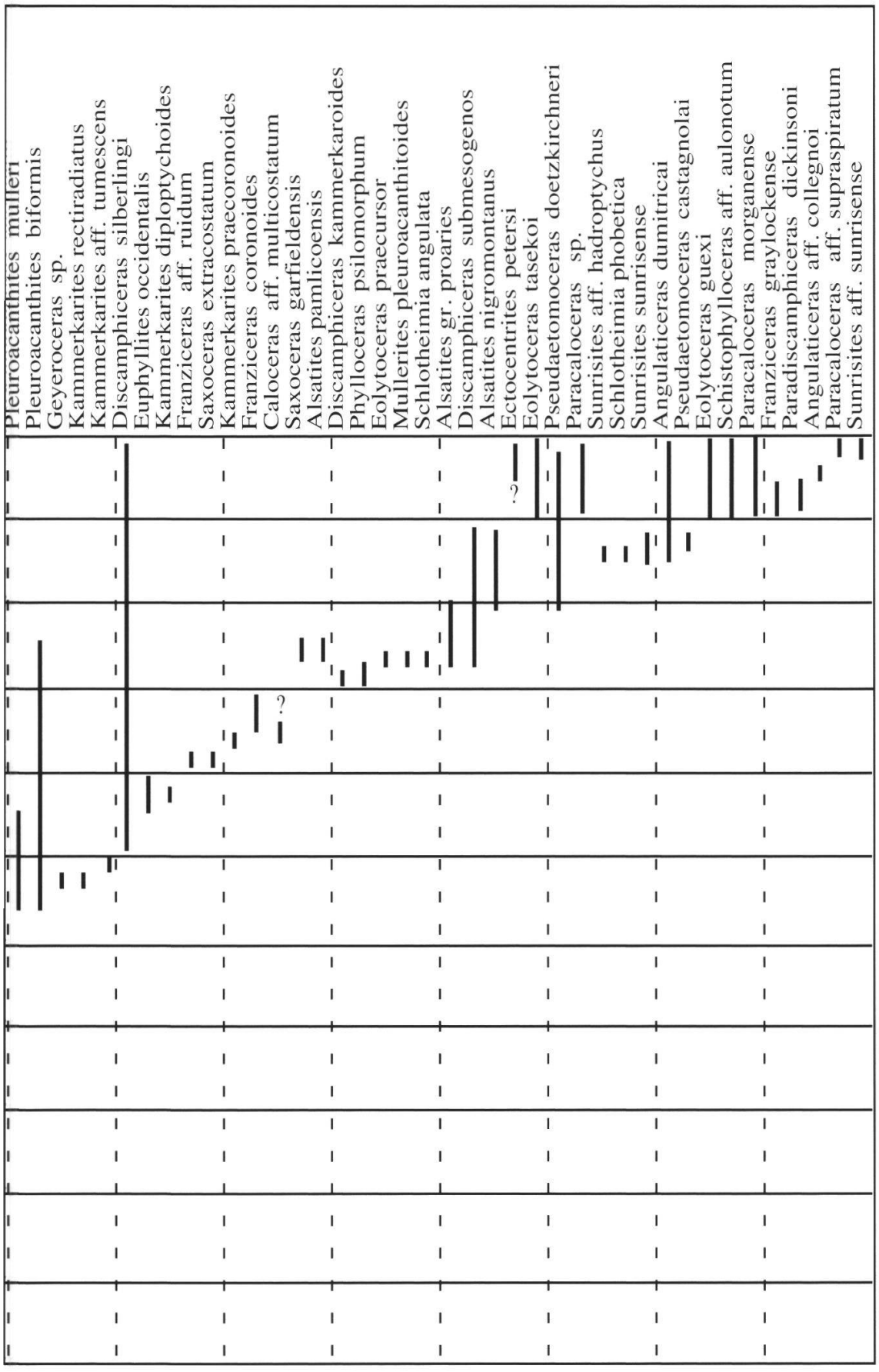


Figure 6.–Composite Range Chart for Hettangian ammonoids in Western North America. Ranges based principally on data from Nevada (Guex 1995; Guex *et al.* 1998; Taylor 1998, 2000; Taylor *et al.* 2000), Oregon (Taylor 1998), Canada (Tipper and Guex 1994), and Alaska (Palfy *et al.* 1999).

appears and *Pleuroacanthites biformis* (SOWERBY) last appears. The upper *Franziceras* beds at Kennecott Point (TIPPER and GUEX 1994) are assigned to this zone.

Sunrisense Zone

Name-bearer, *Sunrisites sunrisense* GUEX; Type section, New York Canyon, Section 1 and beds Z98 through Z110 of GUEX (1995). The zone is represented by the latest occurrences of *Discamphiceras submesogenos* GUEX, *Alsatites nigromontanus* (GUEMBEL) and *Pseudaetomoceras doetzkirchneri* (GUEMBEL), and by the restricted occurrences of *Sunrisites sunrisense* GUEX and *Pseudaetomoceras castagnolai* (Cocchi – CANAVARI). At Pamlico the zone is represented by Assemblage E. This zone is also recognized in Sonora (Fig. 3).

Morganense Zone

Name-bearer, *Gyrophioceras morganense* TAYLOR; Type section, Morgan Mountain, Oregon, Graylock formation. Section depicted in TAYLOR (1998, Fig. 2). The zone is characterized by the restricted occurrences of *Eolytoceras guexi* TAYLOR, *Paracaloceras morganense* TAYLOR, *Franziceras graylockense* TAYLOR, *Paradiscamphiceras dickinsoni* TAYLOR, *Angulaticeras* aff. *collegnoi* (Cocchi – CANAVARI) and *Paracaloceras supraspiratum* (WAEHNER). The zone is also known from Pamlico (TAYLOR 1998, Fig. 6).

Oregonensis Zone

Name-bearer, *Badouxia oregonensis* TAYLOR. Type section, Morgan Mountain, Graylock Formation. Section depicted in TAYLOR (1998, Fig. 2). The zone is characterized by the restricted occurrences of *Discamphiceras ornatum* TAYLOR, *Paracaloceras mineralensis* TAYLOR, *Badouxia oregonensis* TAYLOR, and *Paradiscamphiceras athabascanense* TAYLOR. *Nevadaphyllites compressus* GUEX makes its last appearance in this zone. The zone is also known from Pamlico (TAYLOR 1998, Fig. 6) and it occurs at Taseko Lakes (SMITH and TIPPER 2000) and Kennecott Point (Doetzkirchneri beds in part) (TIPPER and GUEX 1994).

Canadensis Zone

This zone is based in the Taseko Lakes area in British Columbia (FREBOLD 1967). Two subzones are recognized herein. These are the Rursicostatum Subzone followed upsection by the Columbiae Subzone. The zone occurs in the Queen Charlotte Islands (PALFY *et al.* 1994), Taseko Lakes (FREBOLD 1967, SMITH and TIPPER 2000), Oregon (Graylock Formation), and Sonora (TAYLOR *et al.* 1998, Fig. 3).

Rursicostatum Subzone

Name-bearer *Metophioceras rursicostatum* (FREBOLD). Type section, Shoshone Mountains, First Canyon, upper 2 m of limestone beds within Ferguson Hill Member (TAYLOR 2000, Fig. 2, Localities 6815 through 6817. Characteristic species include *Badouxia canadensis* (FREBOLD), *Eolytoceras guexi* TAYLOR, *Paracaloceras retroversicostatum* (CANAVARI), *Pseudaetomoceras shoshonense* TAYLOR, *Metophioceras rursicostatum* (FREBOLD), *Nevadaphyllites microumbilicatus* TAYLOR, *Eolytoceras tasekoi* FREBOLD and *Schlotheimia* ex gr. *stenorhyncha* (LANGE). The lower part of the Canadensis Zone at Taseko Lakes (SMITH and TIPPER 2000, Fig. 2) is referable to this subzone.

THE SINEMURIAN ZONES (Fig. 7)

Columbiae Subzone

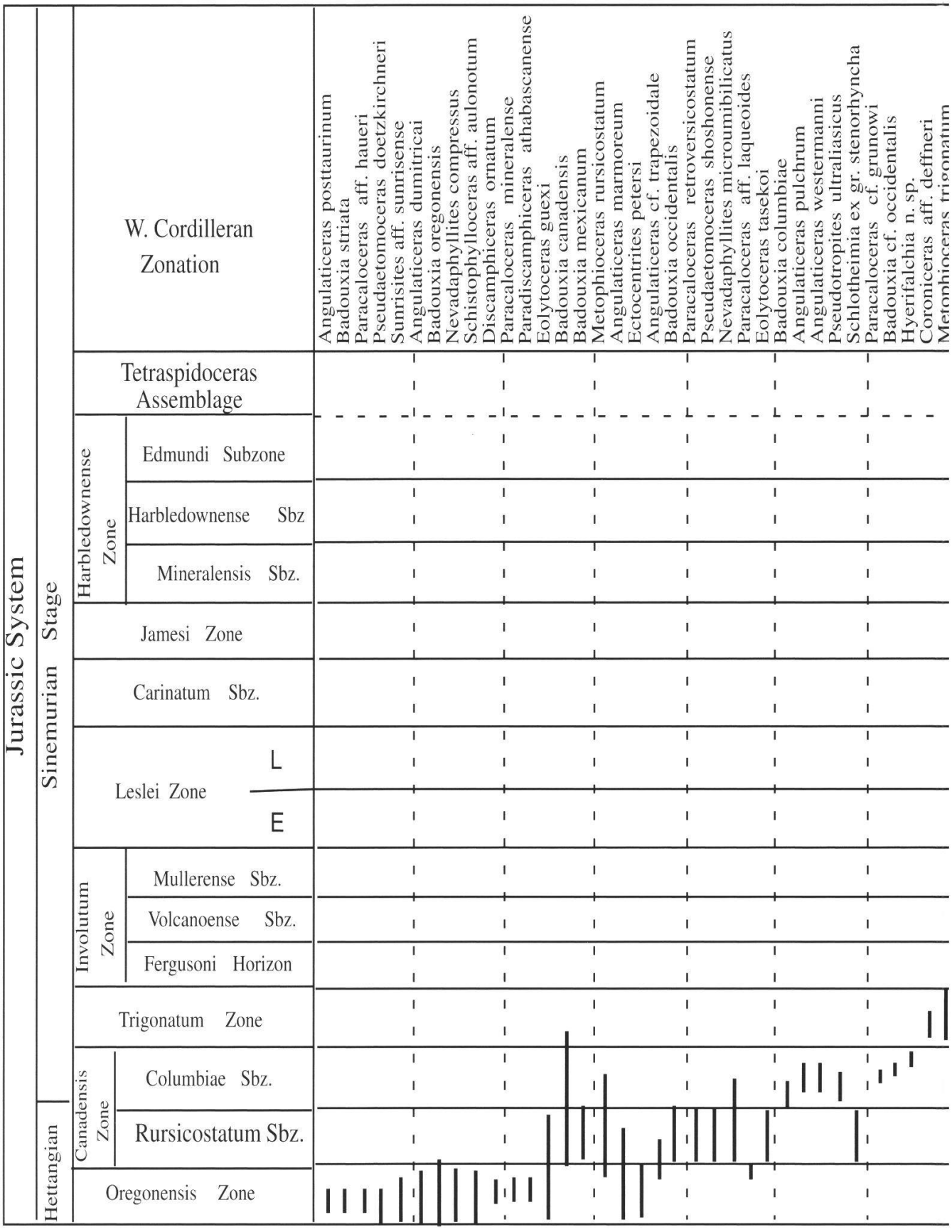
Name-bearer *Badouxia columbiae* (FREBOLD). Type section, Shoshone Mountains, First Canyon, Lower 2.7 m of gray bioclastic limestone beds within Ferguson Hill Member (TAYLOR 2000, Fig. 2, Localities 65 through 24). The zone is characterized by the last occurrences of *Badouxia canadensis* (FREBOLD), *Metophioceras rursicostatum* (FREBOLD) and *Nevadaphyllites microumbilicatus* TAYLOR, and the restricted occurences of *Badouxia columbiae* (FREBOLD), *Hyerifalchia* n. sp, *Paracaloceras* cf. *grunowi* (HAUER), *Metophioceras* aff. *rotarium* (BUCKMAN), and *Paracaloceras concavum* TAYLOR. The upper part of the Canadensis Zone at Taseko Lakes (SMITH and TIPPER 2000, Fig. 2) corresponding closely to the range of *B. columbiae* is referable to this subzone.

Trigonatum Zone (=Trigonatum Assemblage of TAYLOR 1998).

Name-bearer, *Metophioceras trigonatum* TAYLOR (1998). Type Section Shoshone Mountains at First Canyon, 3 – 14.5 m above the base of the Upper division of the Ferguson Hill Member (The uppermost horizon corresponds to the highest bioclastic limestone bed of the upper division at First Canyon (TAYLOR 2000). The zone is well characterized by *Vermiceras densicostatum* TAYLOR, *Coroniceras grantsvillense* TAYLOR, *Coroniceras* aff. *deffneri* (OPPEL), and *Metophioceras trigonatum* TAYLOR (TAYLOR 2000). In Nevada the zone is also known from Milton and New York canyons (TAYLOR 1998).

Involutum Zone (=Involutum Assemblage of TAYLOR 1998).

Name-bearer, *Coroniceras involutum* TAYLOR. Type section New York


Jurassic System
Sinemurian Stage
Hettangian
W. Cordilleran Zonation
Angulaticeras posttaurinum
Badouxia striata
Paracaloceras aff. haueri
Pseudaetomoceras doetzkirchneri
Sunrisites aff. sunrisense
Angulaticeras dumitricai
Badouxia oregonensis
Nevadaphyllites compressus
Schistophylloceras aff. aulonotum
Discamphiceras ornatum
Paracaloceras mineralense
Paradiscamphiceras athabascanense
Eolytoceras guexi
Badouxia canadensis
Badouxia mexicanum
Metophioceras rursicostatum
Angulaticeras marmoreum
Ectocentrites petersi
Angulaticeras cf. trapezoidale
Badouxia occidentalis
Paracaloceras retroversicostatum
Pseudaetomoceras shoshonense
Nevadaphyllites microumbilicatus
Paracaloceras aff. laqueoides
Eolytoceras tasekoi
Badouxia columbiae
Angulaticeras pulchrum
Angulaticeras westermanni
Pseudotropites ultraliasicus
Schlotheimia ex gr. stenorhyncha
Paracaloceras cf. grunowi
Badouxia cf. occidentalis
Hyerifalchia n. sp.
Coroniceras aff. deffneri
Metophioceras trigonatum
Tetraspidoceras Assemblage
Harbledownense Zone
Edmundi Subzone
Harbledownense Sbz
Mineralensis Sbz.
Jamesi Zone
Carinatum Sbz.
Leslei Zone
L
E
Involutum Zone
Mullerense Sbz.
Volcanoense Sbz.
Fergusoni Horizon
Trigonatum Zone
Canadensis Zone
Columbiae Sbz.
Rursicostatum Sbz.
Oregonensis Zone

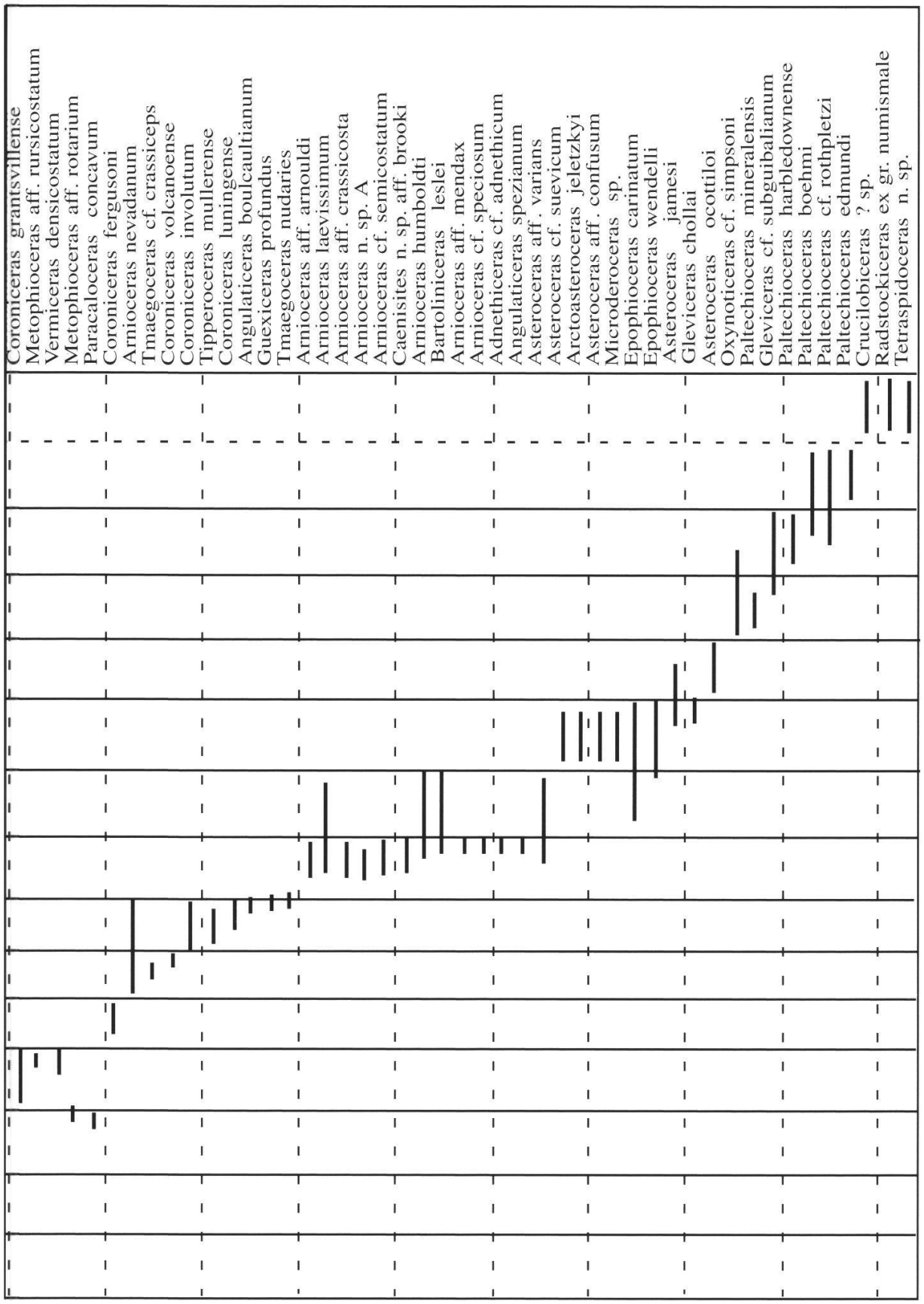


Figure 7.–Composite Range Chart for latest Hettangian and Sinemurian faunas from Western North America. Ranges based primarily on range charts provided herein and literature regarding Nevada (TAYLOR 1998, GUEX 1995) and Canada (FREBOLD 1967, SMITH and TIPPER 2000 and PALFY *et al.* 1994)

Canyon at N38°29.467'; W118°05.726' (base of zone) to N38°29.494'; W118°05.700' (top of zone) in the Ferguson Hill Member of the Sunrise Formation (TAYLOR 1998, Fig. 3). Base of zone demarcated by first bed in sequence of light gray bioclastic limestone beds overlying dark gray siliceous limestone beds. Top of zone corresponds to uppermost bed of the Ferguson Hill Member. The zone is well characterized by the species shown for the zone in TAYLOR (2000, Fig. 3). This zone is divided into a lower horizon and two subzones, as follows.

1) The *Coroniceras fergusoni* horizon is characterized by a single specimen of that species in light gray bioclastic limestone beds approximately 11 m below the top of the Ferguson Hill Member.

2) Volcanoense Subzone (=*C. volcanoense* horizon of TAYLOR 1998). Name bearer, *Coroniceras volcanoense* TAYLOR; Type section, New York Canyon at same location as Involutum Zone. Subzone from 2.7-7 m below top of Ferguson Hill Member and characterized by the first appearance of *Arnioceras nevadanum* (GABB) and the restricted occurrences of *Coroniceras volcanoense* TAYLOR and *Tmaegoceras* cf. *crassiceps* (POMPECKJ).

3) Mullerense Subzone (=*T. mullerense* horizon of TAYLOR 1998). Name-bearer; *Tipperoceras mullerense* TAYLOR. Type section, New York Canyon at same location as Involutum Zone. Subzone from 0–2.7 m below top of Ferguson Hill Member. The subzone is characterized by the last occurrence of *Arnioceras nevadanum* (GABBS) and the restricted occurrences of *Coroniceras involutum* TAYLOR, *C. luningense* TAYLOR, *Tipperoceras mullerense* TAYLOR, *Tmaegoceras nudaries* TAYLOR, and *Guexiceras profundum* TAYLOR. The subzone is also recognized at Milton Canyon (TAYLOR 1998, Fig. 4, "Involutum Assemblage").

Leslei Zone

Name-bearer, *Bartoliniceras* gen. n. *leslei* n. sp. Type Section, New York Canyon at Five Card Draw. Section at N38°29.877', W118°05.625' = basal bed of Five Card Draw Member, Sunrise Formation. Top of section at N38°29.825', W118°05.658' = 5 m above top of Five Card Draw Member. Zone from loc. FF through OO (Fig. 4). The Zone is characterized by the restricted occurrence of *Arnioceras* aff. *arnouldi* (DUMORTIER), and the first appearances of *A. laevissimum* (QUENSTEDT), *A. humboldti* HYATT and *B. leslei* n. sp. The lower part of the *A. arnouldi* assemblage in the Queen Charlotte Islands (PALFY *et al.* 1994) is referable to this zone. This zone also occurs in Sonora (Fig. 3). Based on the record of *Caenisites* n. sp. aff. *brooki*, the fauna from bed ANT2 at Sierra del Alamo may correlate with Northwest European Birchi Zone.

Carinatum Zone

Name-bearer, *Epophioceras carinatum* (SPATH). Type section same as for Leslei Zone. Subzone includes localities TT through YY (Fig. 4). At the type locality it is recognized by abundant *Epophioceras* above the ranges of *Arnioceras laevissimum* (QUENSTEDT), *A. humboldti* HYATT and *Bartoliniceras* gen. n. *leslei* n. sp. (Only a single specimen of *E. carinatum* was found in association with these species of *Arnioceras* in the Late Leslei Zone). The lower part of the *A. varians* assemblage in the Queen Charlotte Islands (PALFY *et al.* 1994) is assigned to this zone. This zone occurs in Sonora (Fig. 3).

Jamesi Zone

Name-bearer *Asteroceras jamesi* n. sp. Type section at Antimonio, Sonora 2-6 m above bed AMJ4 (Fig. 3). The zone includes *Asteroceras jamesi* and *A. ocotilloi* n. sp. above *Epophioceras wendelli* and *Arnioceras*. The upper part of the *A. varians* assemblage in the Queen Charlotte Islands (PALFY *et al.* 1994) is assigned to this zone. This zone occurs in Sonora (Fig. 3).

Harbledownense Zone

Name-bearer *Paltechioceras harbledownense* (CRICKMAY). Type section same as for the Leslei Zone. The zone includes localities 2Z through 3K (Fig. 4). It is well recognized by occurrences of Echioceratids as given in Figures 4 and 5. The *P. harbledownense* assemblage in the Queen Charlotte Islands (PALFY *et al.* 1994) corresponds to this zone.

Three subzones are recognized, as follows.

1) Mineralensis Subzone. Name-bearer *Paltechioceras mineralensis* n. sp. Type section same as for the Leslei Zone. Subzone includes localities ZZ and 3A (Fig. 4).

2) Harbledownense Subzone. Name-bearer *Paltechioceras harbledownense* (CRICKMAY). Type section same as for the Leslei Zone. Subzone includes Localities 3C and 3D (Fig. 4).

3) Edmundi Subzone. Name-bearer *Paltechioceras edmundi* (DUMORTIER). Type section same as for the Leslei Zone. Subzone includes Locality 6908 (Fig. 4). Here *P. edmundi* is also associated with *P. rothpletzi* (BOSE).

Systematic Paleontology

Family Arietitidae HYATT 1874

Genus *Badouxia* GUEX and TAYLOR 1976

Badouxia mexicana n. sp.
Pl. 1, Figs. 3, 4 (Holotype); Figs. 1, 2, 5, 6.

Holotype. Specimen No. 96-2. From Canadensis Zone, Antimonio Formation, Sonora, Mexico, Bed 18. Measurements: D=49.1 mm, U=13.1 mm, WH=14.9 mm, WW=20.8 mm.

Diagnosis. Whorls enlarge rapidly, ribbing dense and prorsiradiate but not strong on venter and in ventro-lateral area.

Description. Specimens referable to this species are moderately involute and have a compressed whorl section. Ribbing is prorsiradiate and straight to gently concave. Costae are closely spaced, arise at the flank base, are strongest in the mid-flank region, and are gently to moderately strongly projected in the ventro-lateral region. The venter is nearly smooth. The body chamber at a shell diameter of 60 mm is nearly smooth on some examples.

Discussion. This species is most like *Badouxia columbiae* (FREBOLD) in shell proportions and ribbing style, but differs in having no accentuation of costation strength in the ventral area.

Genus *Epophioceras* SPATH 1924

Epophioceras wendelli n. sp.
Pl. 7, Figs. 1, 2 (Holotype); Fig. 4-7.

Holotype. Specimen No. 96-9. From Late Leslei Zone, Antimonio Formation, Sonora, Mexico, Bed AMJ-4.
Measurements: D=114.4 mm, U=70.0 mm, H=22.5 mm.

Diagnosis. A stout-whorled and densely ribbed species. Ribbing density increases quite slowly between 40 and 130 mm shell diameter.

Description. The typically evolute shell has a weakly depressed to slightly compressed whorl section and a broadly rounded venter with a low blunt

keel. On the outer whorls the venter has weak tabulate. Ribbing is nearly radial to gently concave and upright to prorsiradiate. Ribbing is dense. At 40-60 mm shell diameter the density is 23-28 ribs per half whorl, while between 80 mm and 120 mm shell diameter the density is 25-30 ribs per half volution.

Discussion. This species somewhat resembles *Epophioceras longicella* (QUENSTEDT) but differs in having a wider whorl section and denser ribbing which does not increase in density markedly with growth. One specimen from AMJ4 differs from the others in having rursiradiate costation and a distinctly sulcate venter on its outer whorl (estimated shell diameter of 90-105 mm). Well preserved and uncrushed specimens are reasonably common at AMJ4.

Genus *Asteroceras* HYATT 1867

Asteroceras jamesi n. sp.
Pl. 5, Figs. 1, 2 (Holotype); Pl. 6, Figs. 1, 4.

Holotype. Specimen No. 96-4. From Humboldti Zone, Antimonio Formation, Sonora, Mexico, Bed AMJ-4. Measurements: D=96.0 mm, U=30.0 mm, WH=39.2 mm, WW=25.5 mm.

Diagnosis. Shell compressed on inner and intermediate whorls, with subparallel whorl sides; strong costation persisting to large shell dimensions.

Description. This species attains a shell diameter of at least 160 mm. The whorl section is moderately compressed and the flanks are subparallel. The venter has tabulae that border a broad keel. Ribbing is radial to gently prorsiradiate and slightly concave to slightly flexuous. Costae retain their strength throughout most of the whorl height, may weaken in the upper 1/4 of the flank height, and fade where they approach the ventral tabulae. Ribbing most commonly is comparatively weak in the inner and intermediate whorls and becomes progressively stronger on the outer whorl between 100 and 160 mm shell diameter.

Discussion. This species has a comparatively compressed whorl section on the inner and intermediate whorls, where there may also be secondary ribbing. The species vaguely resembles *Asteroceras suevicum* (QUENSTEDT), but differs in having the more compressed whorl section on the inner whorls, commonly greater accentuation of ribbing in the outer flank, and markedly

less sulcate venter. *Asteroceras jamesi* differs from *A. ocotilloi* sp. n. by the absence of strong sulci on the venter.

Asteroceras ocotilloi n. sp.
Pl. 4, Fig. 7, 8 (Holotype).

Holotype. Specimen No. 96-8. From Jamesi Zone, Antimonio Formation, Sonora, Mexico, Bed AMJ-11+3. Measurements: D=68.0 mm, U=17.0 mm, WH=31.5 mm.

Diagnosis. Phragmocone strongly bisulcate, costation prorsiradiate and strongly falcoid.

Description. The shell has a moderately compressed whorl section and subparallel flanks. The venter on the phragmocone is tricarinate, with rather broad sulcae. The ribbing on the inner and intermediate whorls is well defined and strongly falcoid. Costation on the outer whorl is weak and poorly defined.

Discussion. *Asteroceras ocotilloi* has well defined sulci as in species such as *A. stellare* (SOWERBY) (to which it bears little resemblance) and is readily distinguished by is markedly flexuous ribbing and degeneration of costation on the outer whorl. This species differs from *A. jamesi* sp. n. in having a markedly tricarinate bisulcate venter.

Family Oxynoticeratidae HYATT 1875

Genus *Gleviceras* BUCKMAN 1918

Gleviceras chollai n. sp.
Pl. 5, Fig. 3, 4 (Holotype).

Holotype. Specimen No. 96-6. From Humboldti Zone, Antimonio Formation, Sonora, Mexico, Bed AMJ-4. Measurements: D=81.3 mm, U=16.0 mm, WH=40.6 mm, WW=27.7 mm.

Diagnosis. Inner flank nearly smooth, no secondary costation on upper flank, rib strength accentuated in ventro lateral area.
Description. The shell is involute and compressed. The umbilical wall is

overhanging, the whorl sides are convergent, and the venter is fastigate and supports a sharp to narrowly rounded keel. Costation is weak and gently flexuous. It is weakest on the lower flank and strongest in the ventro-lateral area. The ribbing trajectory is gently prorsiradiate.

Discussion. This species differs from *G. subguibalianum* in having nearly smooth inner flanks and no secondary ribs in the upper part of the flanks.

Family Echioceratidae BUCKMAN 1913

Genus *Paltechioceras* BUCKMAN 1924

Paltechioceras mineralensis n. sp.
Pl. 8, Fig. 2 (Holotype); Fig. 3.

Holotype. Specimen No. 25650. From Harbledownense Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed 2Z. Measurements: D=88.2 mm, U=53.2 mm, WH=20.0 mm.

Diagnosis. A smaller species of *Paltechioceras* in which ribs fade on the outer whorl. Ribbing densely spaced and prorsiradiate.

Description. This species has closely spaced, dense prorsiradiate ribbing. Ribbing is nearly straight and commonly slightly flexuous. Costation is well defined on the inner and intermediate whorls, but fades markedly in strength on the last volution. The adoral end of the body chamber on some examples is nearly smooth.

Discussion. This species is most like *Paltechioceras harbledownense* (CRICKMAY), but differs in its smaller size and in having ribbing degenerate at comparatively small shell diameters. The species occurs in a narrow stratigraphic interval above *Epohioceras* and just below *P. harbledownense*.

Incertae sedis (?)
Genus *Bartoliniceras* gen. n.

Type species: *Bartoliniceras leslei* n. sp. Pl. 3, Figs. 1, 2 (Holotype).
Derivatio nominis. Dedicated to Dr Annachiara Bartolini.
Material: 3 specimens.

Diagnosis. Small and evolute with strong upper-flank ribbing, peri-ventral nodes and ventral ribs projected. Blunt keel present. Suture line not entirely established but relatively complex at small diameter.

Discussion. The precise taxonomic position of *Bartoliniceras* is not known. It differs from the usual Arietitid by the lack of smooth bands along the blunt keel, and it does not have the constriction of the Ectocentritids.

Bartoliniceras leslei n. sp.

Pl. 3, Figs. 1, 2 (Holotype); 3, 4.

Holotype. Specimen No. 25652. From Leslei Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Coll. NN. Measurements: D=27.5 mm, U=11.6 mm, WH=9.2 mm, WW=8.0 mm.

Diagnosis. Small compressed species with strong upper-flank ribbing which carries well defined peri-ventral nodes.

Description. This is a small species having a shell diameter of up to approximately 35 mm. The whorl section is strongly compressed and the venter is moderately broadly rounded and slightly fastigate. The shell is smooth up to about 5-7 mm shell diameter. Adorally, ventro-lateral bullae appear. The associated ribs are strongest and sometimes restricted to the upper flank. Ribbing may arise on the umbolateral shoulder at shell diameters greater than 15 mm on some comparatively finely ornate specimens. Ribbing is nearly radial to markedly prorsiradiate on the flank and may be gently flexuous. Ribbing abuts against the low blunt keel.

Discussion. Our specimens is possibly related to the poorly preserved specimens described by ERBEN (1956) as «*Geyeria*», which are taxonomically doubtful.

ACKNOWLEDGEMENTS

We thank Carlos Gonzales-Leon for the loan of material from Sonora.

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PLATES 1-8

Plate 1

Figures 1, 2.–*Badouxia mexicana* n. sp. Specimen No. 96-1, Diameter 41.9 mm. From Canadensis Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed 18.

Figures 3, 4.–*Badouxia mexicana* n. sp. Holotype, Specimen No. 96-2, Diameter 49 mm. From Canadensis Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed 18 (Fig. 3).

Figures 5, 6.–*Badouxia mexicana* n. sp. Specimen No. 96-3, Diameter approx. 59 mm. From Canadensis Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed 3.

Figure 7.–*Arnioceras humboldti* HYATT. Specimen 25670. Diameter approx. 70 mm. From Late Leslei Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed QQ.

Figure 8.–*Arnioceras* aff. *arnouldi* (DUMORTIER). Specimen No. 25668. Diameter approx. 110 mm. From Leslei Zone, Sunrise Formation, New York Canyon.

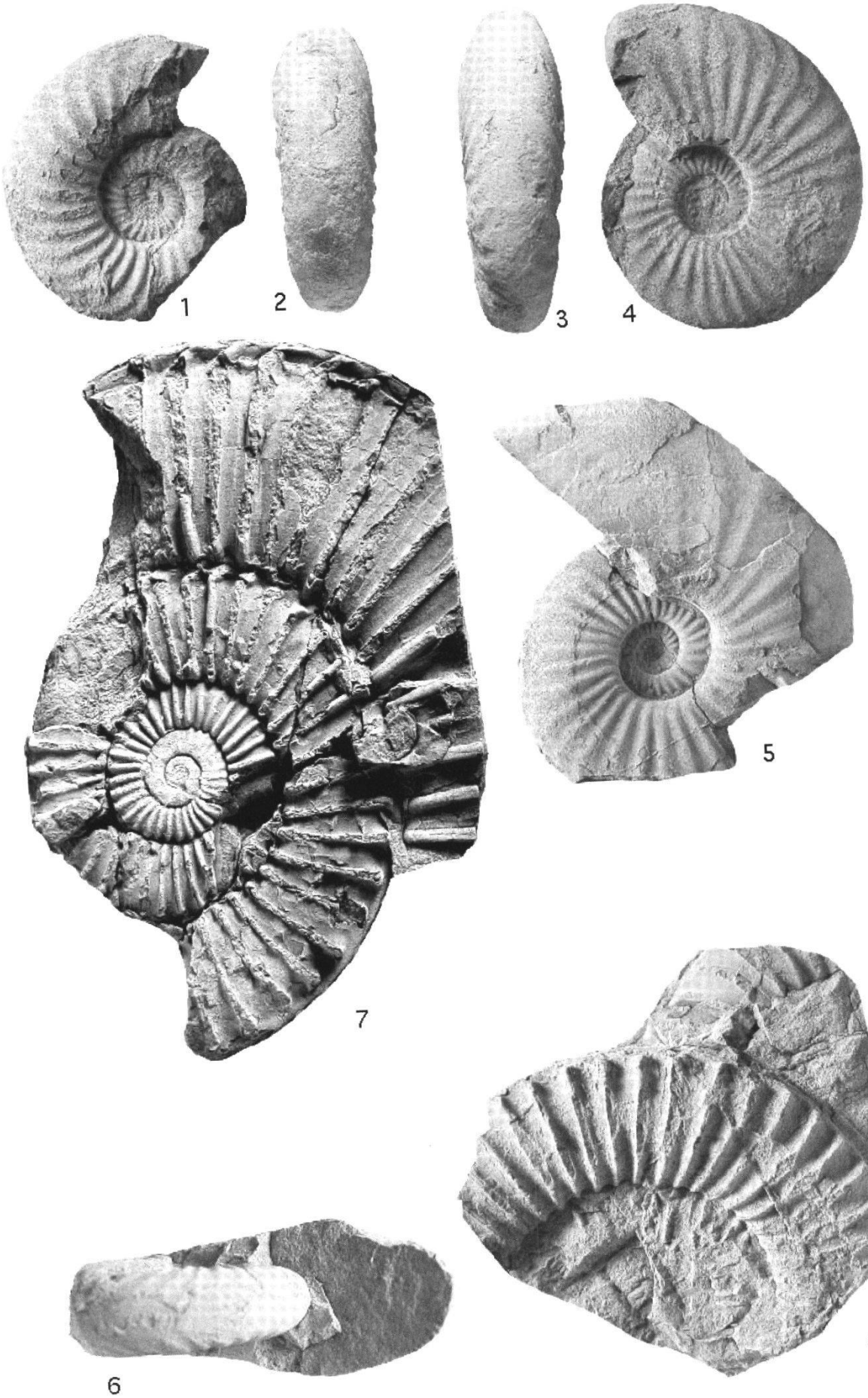
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Plate 2

Figures 1, 2.–*Arnioceras* aff. *arnouldi* (DUMORTIER). Specimen No. 25664. Diameter approx. 44 mm. From Leslei Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed FF.

Figure 3.–*Arnioceras* n. sp. A. Spec, No. ANT2-1. Diameter 34 mm. From Leslei Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed ANT2.

Figure 4.–*Arnioceras* n. sp. A. Spec, No. ANT2-2. Diameter approx. 40 mm. From Leslei Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed ANT2.

Figure 5.–*Arnioceras* cf. *semicostatum* (SIMPSON). Specimen No. 25665. Diameter 75 mm. From Leslei Zone, Sunrise Formation, Shoshone Mountains, Section at First Canyon, Bed 5J.

Figure 6.–*Arnioceras* cf. *semicostatum* (SIMPSON). Specimen No. 25666. Diameter 36 mm. From Leslei Zone, Sunrise Formation, Shoshone Mountains, Section at First Canyon, Bed 5J.

Figure 7.–*Arnioceras laevissimum* (QUENSTEDT). Specimen No. 25663. Diameter approx. 30 mm. From Leslei Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed QQ.

Figure 8.–*Arnioceras* cf. *semicostatum* (SIMPSON Spec, No. ANT2-3.). Diameter 34 mm. From Leslei Zone, Antimonio Formation, Sonora Mexico, Antimonio Section, Bed ANT2.

Figure 9.–*Arnioceras laevissimum* (QUENSTEDT). Specimen No. 25662. Diameter 35 mm. From Leslei Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed 2Q1.

Figure 10.–*Arnioceras laevissimum* (QUENSTEDT). Specimen No. 25661. Diameter approx. 25 mm. From Leslei Zone, Sunrise Formation, Shoshone Mountains, Section at First Canyon, Bed 5K.

Figure 11.–*Arnioceras* aff. *arnouldi* (DUMORTIER). Specimen No. 25667. Diameter 139 mm. From Leslei Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed KK.

Figure 12.–*Arnioceras* n. sp. A. Spec, No. ANT2-14. Diameter 70 mm. From Leslei Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed ANT2.

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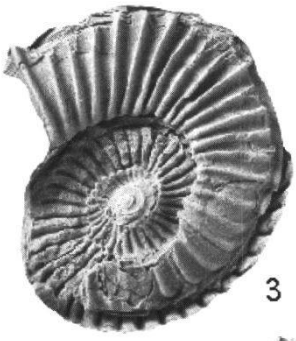

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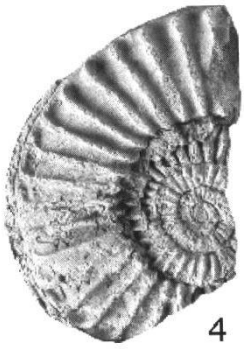

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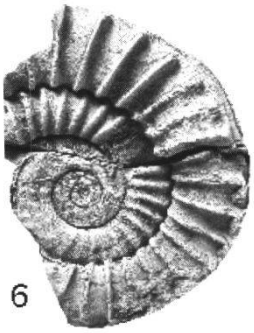

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Plate 3

Figures 1, 2.–*Bartoliniceras* gen. n. *leslei* n. sp. Specimen No. 25652 (Holotype). Diameter approx. 27.5 mm. From Leslei Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed NN (Fig. 4).

Figure 3.–*Bartoliniceras* gen. n. *leslei* n. sp. Specimen No. 25654. Diameter 40 mm. From Leslei Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed MM.

Figure 4.–*Bartoliniceras* gen. n. *leslei* n. sp. Specimen No. 25653. Diameter 37 mm. From Leslei Zone, Sunrise Formation, Shoshone Mountains, Section at First Canyon, Bed 5K.

Figure 5.–*Caenisites* n. sp. aff. *brooki* (J. SOWERBY). Specimen No. ANT2-4. Diameter 33 mm. From Leslei Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed ANT2.

Figure 6.–*Arnioceras humboldti* HYATT. Specimen No. 25658. Diameter approx. 156 mm. From Early Leslei Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed. QQ.

Figure 7.–*Caenisites* n. sp. aff. *brooki* (J. SOWERBY). Specimen No. ANT2-5. Diameter 45 mm. From Leslei Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed ANT2.

Figure 8.–*Arnioceras humboldti* HYATT. Specimen No. 25657. Diameter approx. 158 mm. From Early Leslei Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed PP.

Figure 9.–*Caenisites* n. sp. aff. *brooki* (J. SOWERBY). Specimen No. ANT2-6. Diameter approx. 38 mm. From Leslei Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed ANT2.

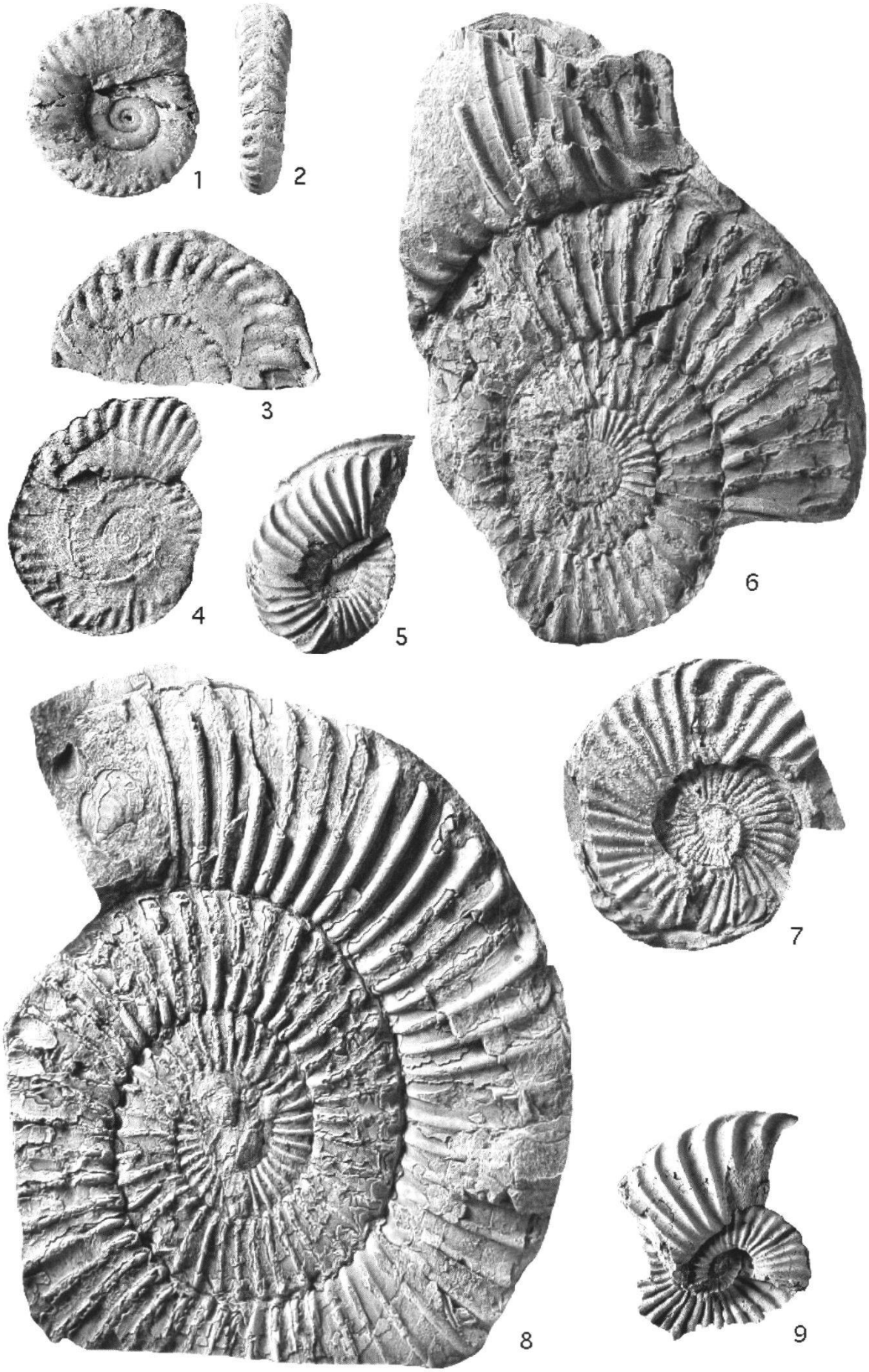
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Plate 4

Figure 1.–*Asteroceras* cf. *suevicum* (QUENSTEDT). Specimen No. 25661. Diameter approx. 85 mm. Float from Humboldti Zone, Sunrise Formation, New York Canyon, Five Card Draw Section.

Figures 2, 3.–*Caenisites* n. sp. aff. *brooki* (J. SOWERBY). Specimen No. ANT2-7. Diameter 34 mm. From Leslei Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed ANT2.

Figure 4.–*Asteroceras* sp. Specimen No. 25669. Diameter 35 mm. From Carinatum Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed VV.

Figure 5.–*Caenisites* n. sp. aff. *brooki* (J. SOWERBY). Specimen No. ANT2-8. Diameter approx. 34 mm. From Leslei Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed ANT2.

Figure 6.–*Caenisites* n. sp. aff. *brooki* (J. SOWERBY). Specimen No. ANT2-9. Diameter 65 mm. From Leslei Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed ANT2.

Figures 7, 8.–*Asteroceras ocotilloi* n. sp. Specimen No. 196-8 (Holotype). Phragmocone diameter 68 mm. From Jamesi Zone, Antimonio Formation, Sonora, Mexico, Sierra del Alamo Section, Bed 11+3m (Fig. 3).

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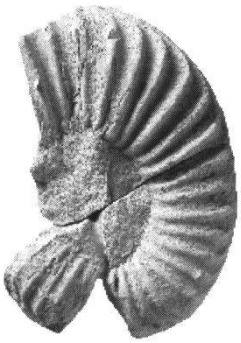

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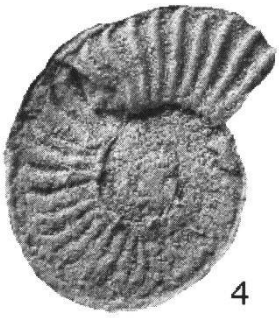

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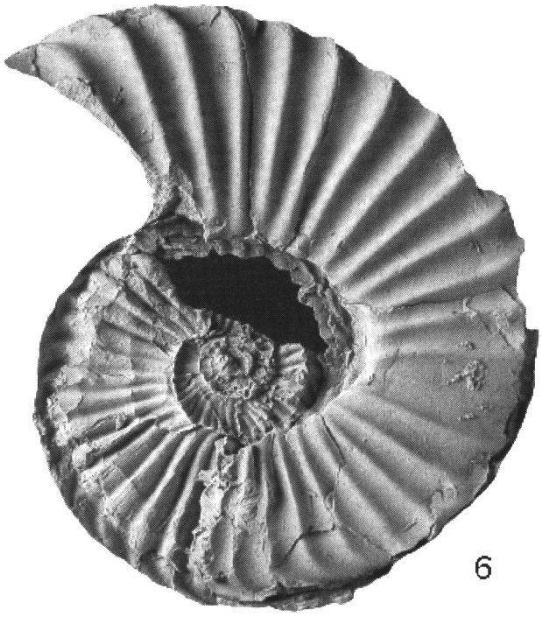

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Plate 5

Figures 1, 2.–*Asteroceras jamesi* n. sp. Specimen No. 96-4 (Holotype). Diameter 96 mm. From Carinatum Zone, Antimonio Formation, Sonora, Mexico, Sierra del Alamo Section, Bed AMJ4 (Fig. 3).

Figures 3, 4.–*Gleviceras chollai* n. sp. Specimen No. 96-6 (Holotype). Diameter 81.3 mm. From Carinatum Zone, Antimonio Formation, Sonora, Mexico, Sierra del Alamo Section, Bed AMJ4 (Fig. 3).

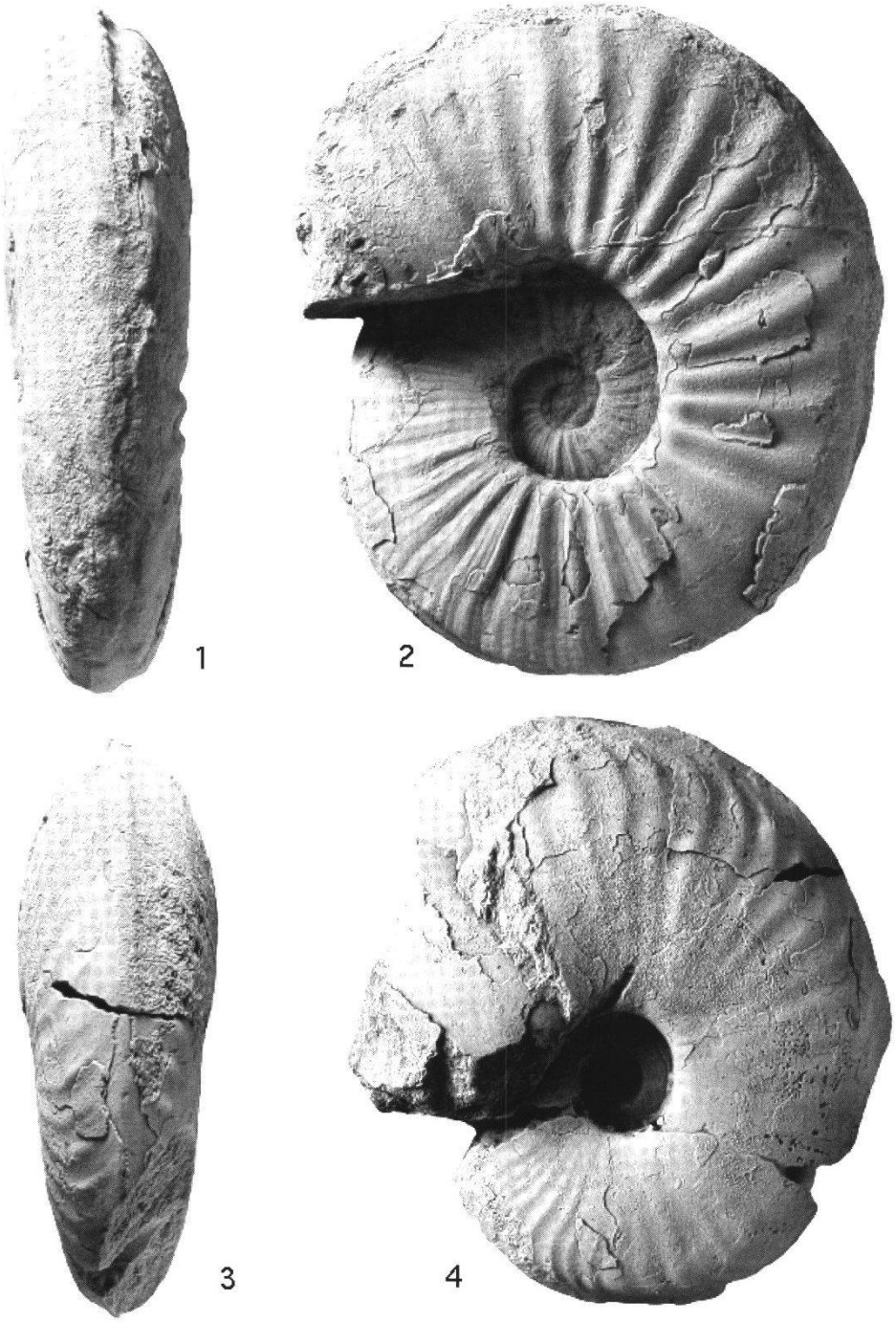
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Plate 6

Figure 1.–*Asteroceras jamesi* n. sp. Specimen No. 96-7. Diameter 90 mm. From Carinatum Zone, Antimonio Formation, Sonora, Mexico, Sierra del Alamo Section, Bed AMJ4.

Figures 2, 3.–*Caenisites* n. sp. aff. *brooki* (J. SOWERBY). Specimen No. ANT2-15. Diameter 65 mm. From Leslei Zone, Antimonio Formation, Sonora Mexico, Sierra del Alamo Section, Bed ANT2.

Figure 4.–*Asteroceras jamesi* n. sp. Specimen No. 96-5. Diameter 173 mm. From Jamesi Zone. Antimonio Formation, Sonora, Mexico, Sierra del Alamo Section, Bed 12.5.

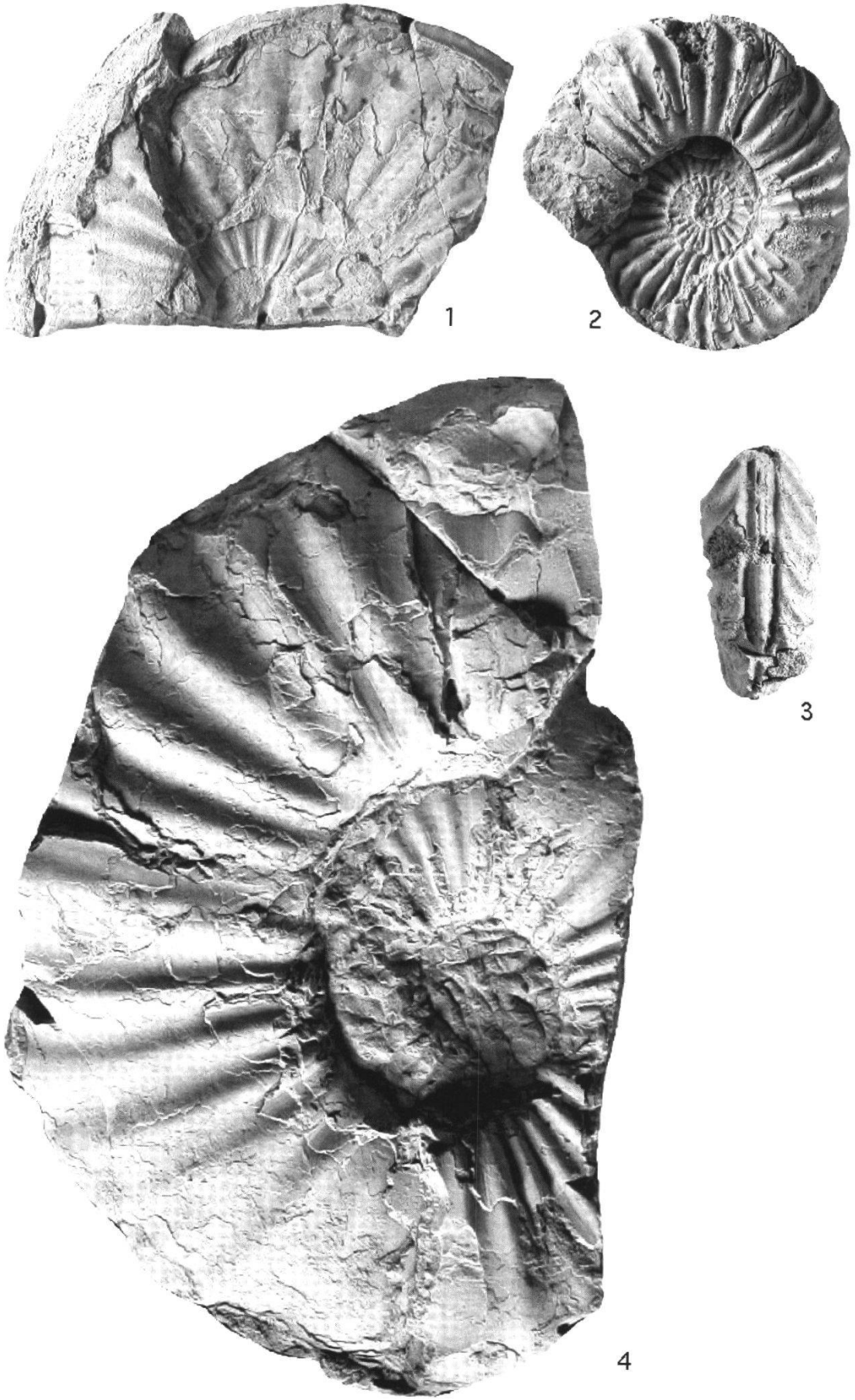
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Plate 7

Figures 1, 2.–*Epophioceras wendelli* n. sp. Specimen No. 96-9 (Holotype). Diameter 114.4 mm. From Carinatum Zone. Antimonio Formation, Sonora, Mexico, Sierra del Alamo Section, Bed AMJ4 (Fig. 3).

Figure 3.–*Epophioceras carinatum* (SPATH). Specimen No. 25659. Diameter 52 mm. From Carinatum Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed 2W.

Figures 4, 5.–*Epophioceras wendelli* n. sp. Specimen No. 96-11. Diameter 35 mm. From Carinatum Zone. Antimonio Formation, Sonora, Mexico, Sierra del Alamo Section, Bed AMJ4.

Figures 6, 7.–*Epophioceras wendelli* n. sp. Specimen No. 96-10. Diameter 76 mm. From Carinatum Zone. Antimonio Formation, Sonora, Mexico, Sierra del Alamo Section, Bed AMJ4.

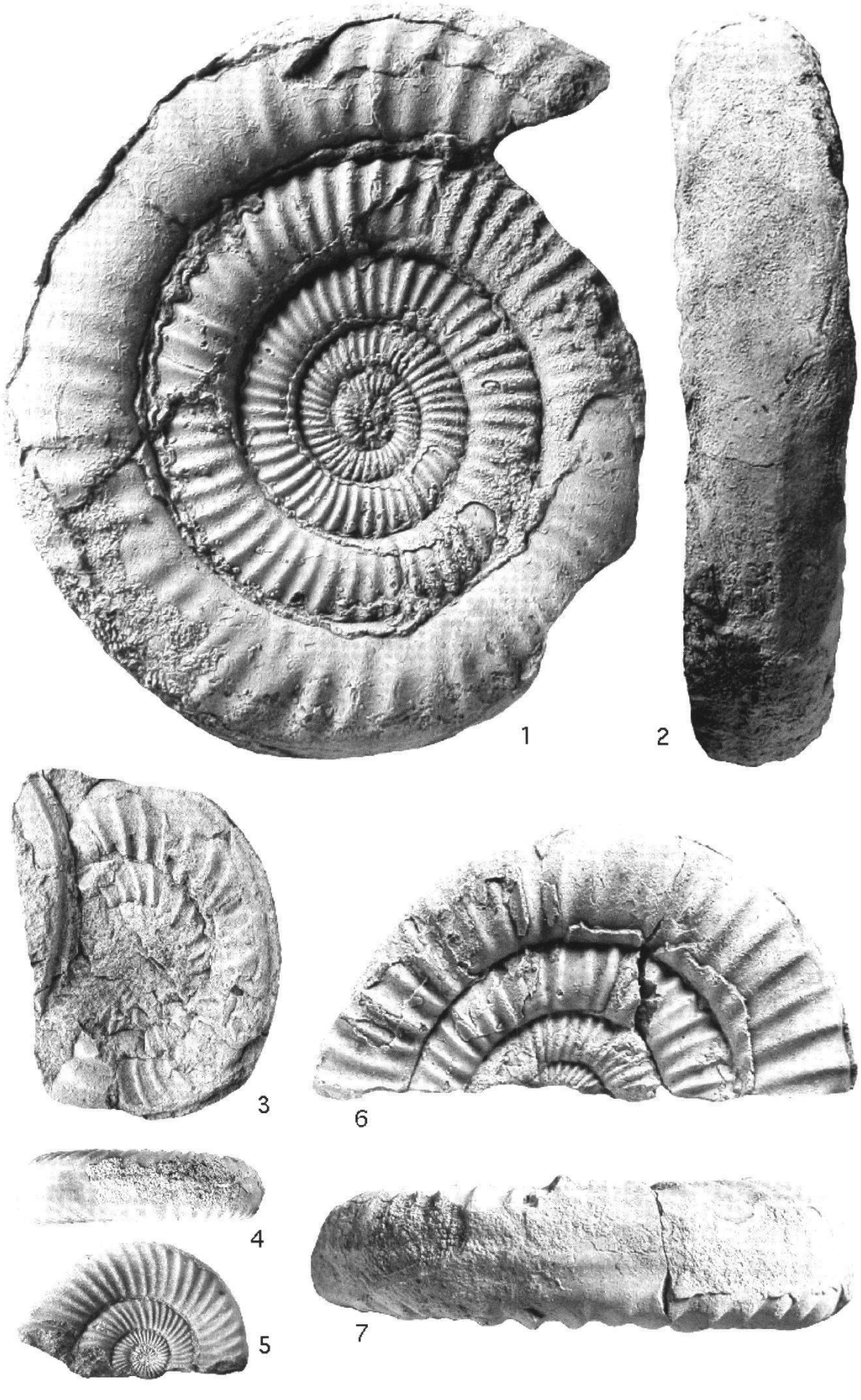
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Plate 8

Figure 1.–*Paltechioceras harbledownense* (CRICKMAY). Specimen No. 25655. Diameter 118 mm. From Harbledownense Subzone. Sunrise Formation, Shoshone Mountains, Section at First Canyon, Bed 5S.

Figure 2.–*Paltechioceras mineralensis* n. sp. Specimen No. 25650 (Holotype). Diameter 88.2 mm. From Mineralensis Subzone. Sunrise Formation, New York Canyon, Five Card Draw Section, Bed 2Z (Fig. 4).

Figure 3.–*Paltechioceras mineralensis* n. sp. Specimen No. 25651. Diameter 58 mm. From Mineralensis Subzone. Sunrise Formation, New York Canyon, Five Card Draw Section Float below Bed 2Z.

Figure 4.–*Epophioceras carinatum* (SPATH). Specimen No. 25660. Diameter 74 mm. From Carinatum Zone, Sunrise Formation, New York Canyon, Five Card Draw Section, Bed QQ.

Figures 5, 6.–*Paltechioceras* (*Orthechioceras*) *edmundi* (DUMORTIER). Specimen No. 25656. Diameter 37.5 mm. Edmundi Subzone, Sunrise Formation, New York Canyon, Five Card Draw Section.

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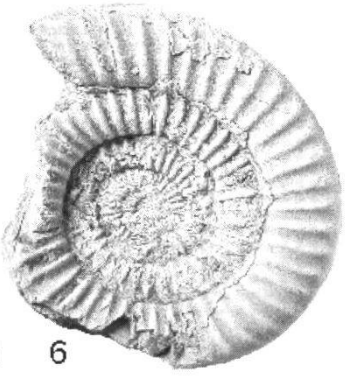

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