PALEONTOLOGY OF TWO NORTH AMERICAN TRIASSIC REEF FAUNAS: IMPLICATIONS FOR TERRANE PALEOGEOGRAPHY

By

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Massive Upper Triassic (Norian) reef limestone at Lime Peak, Yukon and smaller deposits of reef associated carbonates at Long Creek, Alaska contain a variety of shallow-water marine fossils that are significant for paleobiogeographic reconstruction of terranes. Eleven scleractinian coral species and the alatoform bivalve, *Wallowaconcha* cf. *W. raylenea* are described critically for the first time from the Stikine terrane at Lime Peak, Yukon. In addition, the new discovery of five scleractinian coral species, the alatoform bivalve *Wallowaconcha* sp., and one spongiomorph is also reported from the Chulitna terrane at Long Creek, Alaska.

The newly described coral species from the Stikine and Chulitna terranes were added to a database comprised of 57 Triassic scleractinian coral species from seven North American displaced terranes, and one Siberian terrane. The database was subjected to probabilistic similarity, cluster, and parsimony analysis in order to reconstruct terrane paleogeography based on faunal similarity. Results from the statistical analyses were compared with known paleomagnetic, stratigraphic, and tectonic data, as well as other paleogeographic interpretations to create a paleobiogeographic terrane reconstruction for the Triassic. Observations of the occurrence of wallowaconchid bivalves in both the Stikine and Chulitna terranes also were incorporated into the terrane reconstruction.

Results from the probabilistic similarity, cluster, and parsimony analyses are generally conformable and show temporal and spatial relationships within two main groups: 1) the Stikine, Chulitna, Quesnel, Eastern Klamath, Luning Allochthon, and Antimonio terranes, and 2) the Wrangellia, Alexander, Wallowa, and Koryak terranes. These groups are interpreted to represent at least two ancient island arc chains that developed along the western margin of North America during Triassic time.

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CHAPTER I

INTRODUCTION

The advent of the theory of plate tectonics paved the way for new ideas and answers in geosciences. One important concept derived from the theory is the notion of the displaced terrane. The displaced terrane is defined as a fault-bounded package of rock consisting of internally homogeneous stratigraphy, tectonics, and history that differs from both neighboring regions and adjoining continental masses (Coney et al., 1980). Areas once considered geologically complex and incongruent with adjacent structure, are now understood as displaced terranes. Extensive research of western North America has revealed many terranes within the Cordillera (Fig. 1) (Coney et al., 1980; Jones et al., 1982). Study of these Cordilleran terranes aids in the reconstruction of the geological history of western North America.

Composed of a mosaic of displaced terranes, the Cordillera holds important information about the biological and geographical evolution of North America's western margin. By studying the paleontology and geology of displaced terranes, a better understanding of biologic and tectonic processes at play during Cordilleran development is established. An important aspect of this type of terrane analysis is paleogeography.

Paleogeography is important for tectonostratigraphic analysis, determining origination and offset of displaced terranes, and establishing relationships between terranes. Two essential components of reconstructing terrane paleogeography are biogeographic correlation with fossils among terranes and

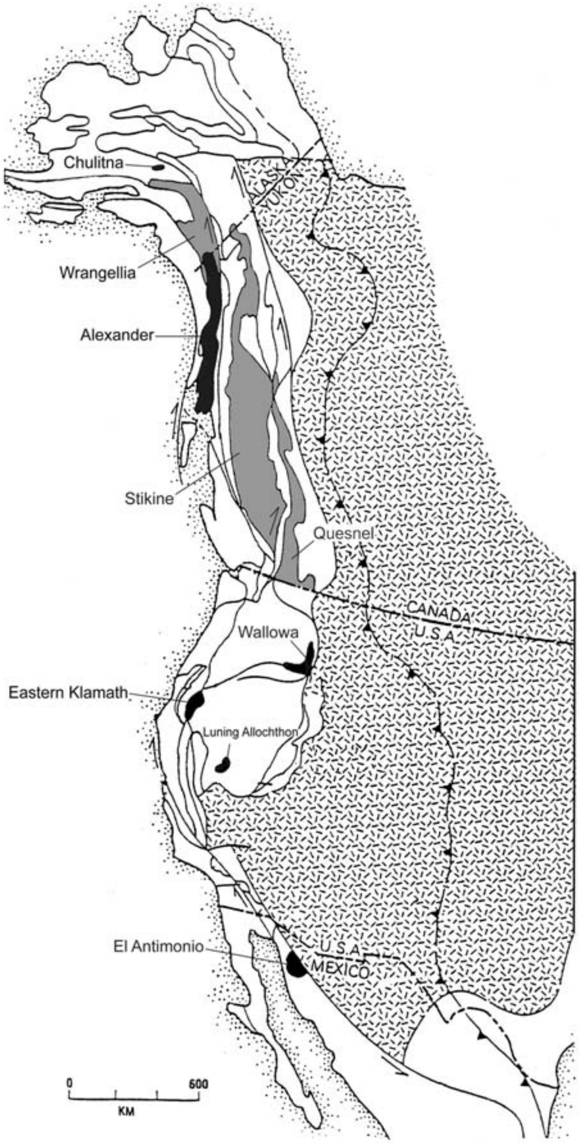

Figure 1. Generalized map of Cordilleran displaced terranes. The dashed pattern represents North American autochthonous cratonic basement, the barbed line shows the eastern limit of Mesozoic – Cenozoic deformation, and the arrows indicate direction of major strike-slip movements. Highlighted are the terranes discussed in this thesis, note that only the northern Wrangellia terrane is depicted (modified from Coney et. al., 1980).

restoration of paleomagnetism to ascertain original, pre-accretionary latitude of terranes. Biogeographic studies involve a comparison of the spatial and temporal distribution of fauna between terranes in order to track tectonic displacement through time and test existing plate tectonic reconstructions (Aberhan, 1998, p. 129). Paleomagnetic analysis requires an evaluation of any relict magnetism within iron-rich minerals of igneous rocks. This permanent magnetic signature records the different states of the Earth's magnetic field and the magnetic inclinations relative to latitude. Knowledge of these data allow resolution of the ancient paleolatitude when the rock formed. Many tectonostratigraphic terranes are of island arc affinities and their magnetic signatures for the Triassic consistently indicate low paleolatitudes.

The recognition of an irregular distribution of marine Triassic fossils throughout North America is an incipient principle of the earliest identification and interpretation of Cordilleran terrane displacement (Tozer, 1970; Nichols and Silberling, 1979). Analysis of Cordilleran tropical to subtropical reefal type fossil associations found in thick deposits of Permian and Triassic limestone concurs with paleomagnetic signatures to determine that many North American displaced terranes were derived from lower, tropical latitudes. However, these analyses have not yet resolved the inherent problem of which hemisphere, north or south, the latitudinal coordinates are constrained. Currently, most paleobiogeographic and paleomagnetic studies involving Cordilleran limestone deposits are limited since fossil preservation is low due to recrystallization or thermal alteration and they lack minerals that retain remnant magnetism. Current studies are able to resolve with confidence only paleolatitude and little is known about Pre-Jurassic longitude of terranes (Ross and Ross, 1985; Wilson et al., 1989; Coney, 1990). There also exists, due to poor preservation and lack of discovery, insufficient craton-associated Triassic reef deposits, further obscuring the terrane - craton relationship. Both the inability to discern paleolongitude through paleomagnetism and the lack of good biogeographic correlation between terranes and the craton are problematic. New methods for determining longitudinal paleogeography of terranes are necessary to improve Triassic paleogeographic reconstructions. One prevalent method involves using statistical analysis of faunal distribution to reconstruct biogeographic patterns and spatial relationships in order to test possible paleogeographic locations of terranes.

Statistical approach to paleobiogeography

Paleontological similarity between different geographical areas originally provided supporting evidence for the theory of plate tectonics. However, early paleogeographic studies relied more on paleomagnetic data, leaving paleobiogeographers to calculate distributional data within the confines of geophysical paleogeographic maps (Henderson and Heron, 1977). Paleontology is taking a more active role in the interpretation of paleogeography by incorporating modern biogeography theory in the analysis. Today, paleontologists and paleobiogeographers are using fossils to reinterpret paleogeographic maps and to “assist in the resolution of pre-Cretaceous paleogeographies [during intervals of geologic time] for which sea-floor spreading data in the form of datable magnetic anomaly patterns are unavailable" (Henderson and Heron, 1977, p. 1).

Multivariate statistics, probabilistic estimates of diversity and similarity, and parsimony analysis of endemicity provide new and valid approaches to the comparison of fossil faunas to reconstruct North American terrane paleogeography (Henderson and Heron, 1977; Raup and Crick, 1979; Belasky, 1992). These statistical methods are shown to constrain paleolongitude and provide data needed to predict spatial relationships between displaced terranes during Permian to Jurassic times (for the Permian: Belasky and Runnegar, 1994; Hanger, 1996; Yarnell et al., 1997; for the Jurassic: Aberhan, 1998). Recent research using probabilistic methods to compare modern distributions of Indo-Pacific corals and foraminifers with Permian rugose coral diversity have placed longitudinal constraints on reconstructions of North American Permian geography (Belasky and Runnegar, 1994). Another study using Permian brachiopod diversity patterns shows that cluster analysis, probabilistic similarity, and parsimony analysis produce highly conformable results in the paleogeographic reconstruction of South America (Hanger, 1996). The results of these studies are significant and greatly support the use of multiple statistical methods for paleobiogeographic reconstruction. When utilized in conjunction with paleobiologic and paleomagnetic data, probabilistic analysis is an important tool that provides necessary paleobiogeographical information to reconstruct original location of displaced terranes.

Purpose and scope of study

Common occurrences of Tethyan-like corals and other reef-building taxa are recognized in the Cordilleran region of western North America (Stanley, 1994a). However, due to poor development, smaller-scale, and remote locations, North American Triassic reefs and reef-like associations are studied less intensely than their European and Asian counterparts (Fig. 2). Current research and comparisons produce little information about the evolution and paleogeography of Triassic carbonate buildups outside the Tethys realm. Further investigation of Triassic reef deposits in Cordilleran terranes provides valuable data for understanding and reconstructing terrane history.

Two Triassic reef localities which are the focus of this study, Lime Peak and Long Creek, occur within two seemingly dissimilar tectonic blocks, the Stikine and Chulitna terranes, respectively. Geologic and some paleontologic studies of these areas are available, but neither have focused on Triassic corals and other reef-building fossils or their paleogeographic significance. Only bivalve faunas that indicate origin in low-latitudes are reported in both terranes (Silberling et al., 1997). Paleontological description and comparison of fossil taxa present in terranes is an important part of the process to resolve geologic and geographic relationships between terranes.

The purpose of this study is to introduce previously poorly known coral faunas from Lime Peak, Yukon and unknown faunas from Long Creek, Alaska,

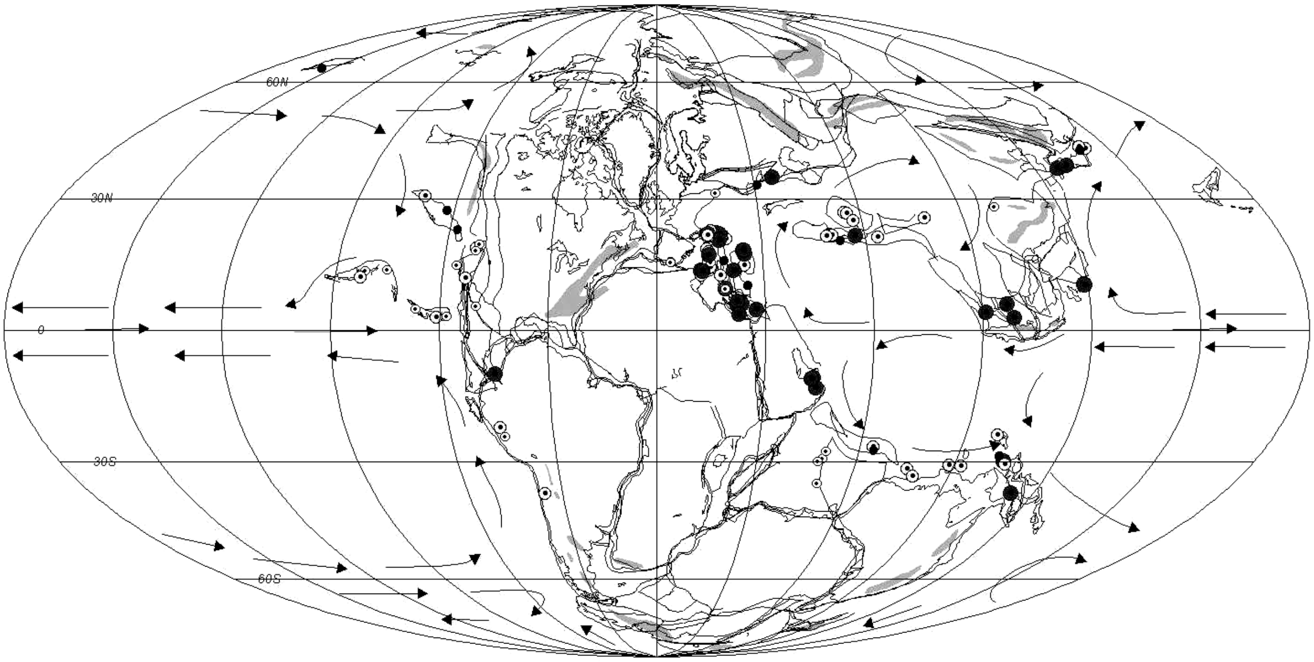

Figure 2. Map of Pangea and the Tethys Sea during the Late Triassic. The bulls-eye points indicate known reef deposits and the arrows show probable ocean current flow. Note the interpretation of island arcs containing reef deposits outward of western North America

and incorporate them, along with coral faunas from seven other North American localities and one Siberian locality, in an analysis using three proven statistical methods to interpret terrane paleogeography during the Triassic. The coral paleontology at Lime Peak and Long Creek is new and has great significance for reconstructing ancient North American terrane geography. The reef and reefal fossils from these localities provide new and useful data with which to compare a select group of seven Cordilleran terranes and one Siberian terrane. The list of coral used in the statistical analysis was compiled using data from the literature, on Triassic coral from the Koryak terrane in Siberia (Melnikova and Bychkov, 1986) and the following Cordilleran terranes: Alexander, Antimonio, Eastern Klamath, Luning Allochthon, Quesnellia, Wallowa, and Wrangellia (Schlichtholz, 1997; Goodwin, 1998). This study applies statistical approaches for paleobiogeographical reconstructions toward a reconstruction of Triassic terrane paleogeography.

Similar paleogeographical studies using these methods were applied to Permian and Jurassic invertebrate fossils, yet no work based on Triassic cnidarians is yet available. This study will help bridge the gap between Permian and Jurassic paleogeography suggested in previous literature (Stevens et al., 1990; Belasky and Runnegar, 1994; Aberhan, 1998) by proposing spatial relationships among Triassic terranes in North America, as well as testing the efficacy of established methods and conclusions used for terrane reconstruction.

CHAPTER II

FIELD LOCALITIES AND METHODS

Fieldwork

Fieldwork in Yukon Territory and Alaska was conducted over a one-month period during the summer of 1998. The main purpose of this fieldwork included fossil collection, general reconnaissance of the geology, and the search for new localities. Consultation with local geologists in Yukon and Alaska and review of geologic maps and literature further assisted fieldwork. Generous contributions of locality information and paleontological samples (see “Acknowledgements”) provided substantial research material.

In the Yukon, field investigation took place at five Triassic carbonate localities in the vicinity of the city of Whitehorse (Fig. 3). The localities include Lime Peak, Pilot Mountain Subdivision, Emerald Lake, Canyon Mountain (regionally known as Gray Mountain), and upper Cap Creek. Each locality was selected based on the abundance and preservation of carbonate rock and the presence of fairly well-preserved fossils of Upper Triassic (Norian) age. Lime Peak and upper Cap Creek localities were accessed by Jet Ranger helicopter, and the remaining sites could be reached by automobile. Fossil samples were collected and the general lithology was observed. Latitude and longitude geographical coordinates were recorded using a Magellan GPS 2000 instrument. Table 1 gives the geographic location and lithology of each locality.

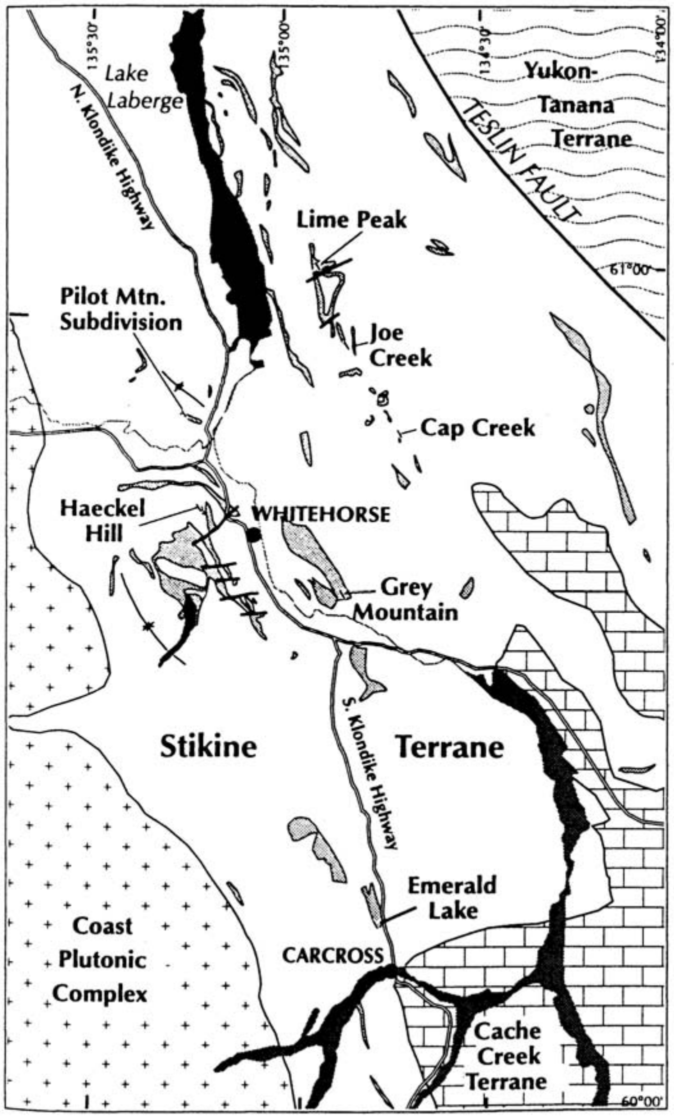

Figure 3. Map showing five Upper Triassic carbonate fossil localities near Whitehorse, Yukon Territory, Canada (from Yarnell et al, 1998).

Fieldwork in Alaska was based out of the Golden Zone Mine camp located in the Chulitna District, just outside the southeast border of Denali National Park near the town of Cantwell about 140 miles north of Anchorage (Fig. 4). The camp was formerly accessible by road from Colorado station, but the main bridges are washed out and the camp is accessible only by helicopter or six-wheeled vehicle. The Triassic reef limestone crops out a few meters northeast of, and along the stream cut of Long Creek. The locality was visited both by helicopter and by foot. Karen Clautice of The Alaska Division of Geological and Geophysical Surveys (ADGGS) provided valuable site information and helicopter support. The geographic location and lithology was observed and fossil samples were collected (Table 1).

Laboratory Methods

The main focus of the analysis was identification of fossil scleractinian corals and observation of associated macrofossils. Samples contributed originally by Dr. Pamela Reid, Mr. Craig Hart, Dr. Robert Blodgett, and Ms. Sarah Schlichtholz and subsequently housed in the UM Museum of Paleontology were combined with samples collected during fieldwork to provide abundant material for study. About 200 hand samples were cut, polished, or thin sectioned in the University of Montana rock sample preparation lab, while four large rock samples were cut in Whitehorse, Yukon, at the Yukon Geology Program rock lab facility. A total of 64 thin sections, 38 from Lime Peak and 26 from Long Creek, were

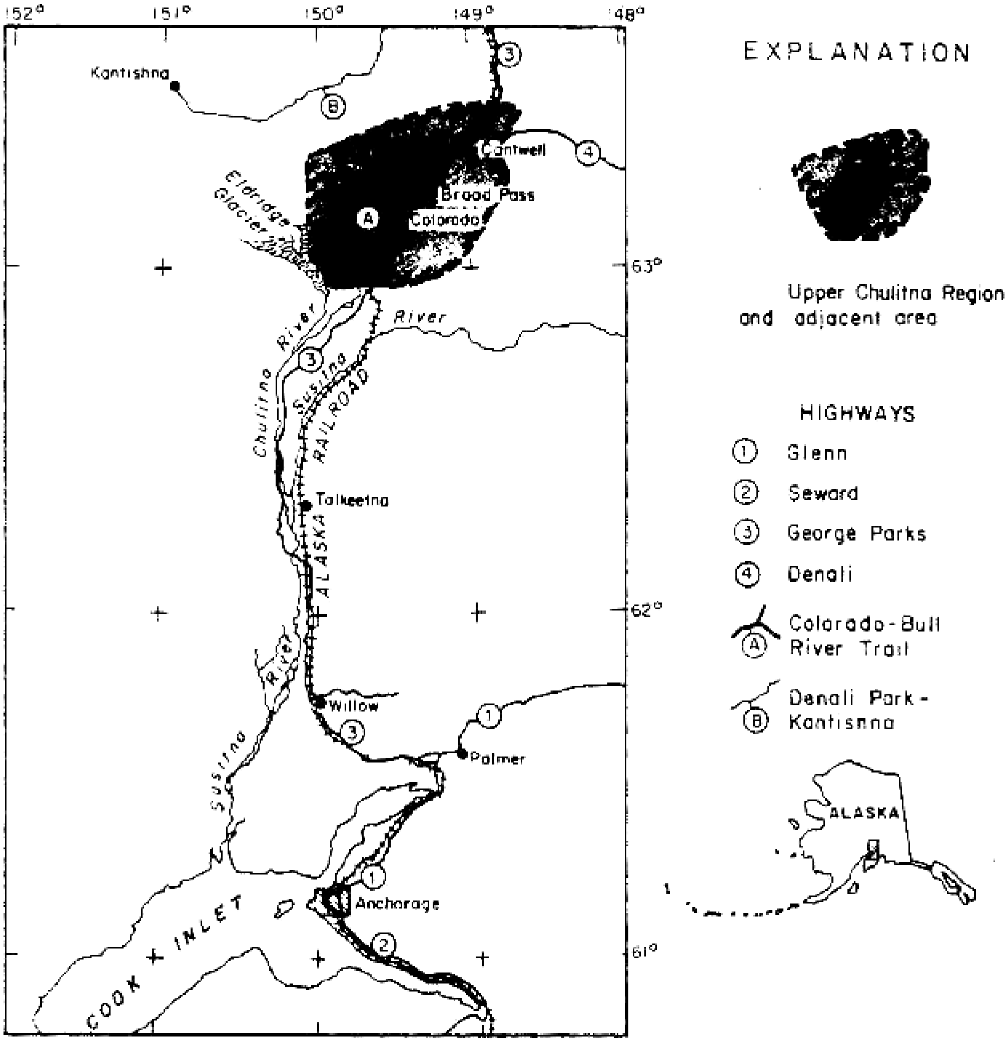

Figure 4. Map showing the Upper Chulitna region located on the south flank of the Alaska Range, about 140 miles north of Anchorage (from Hawley et al., 1987).

Table 1. Table showing geographic location and description of each site investigated for this study.

Locality	Lat. / Long.	Map	Lithology	Age
Lime Peak	61°04'N 134°54'W	(Canada) NTS 105E/2	Massive, light brown to gray thick-bedded reefal limestone, forms distinctive peaks	Early to Late Norian based on conodonts (England, 1980), the formainifer *Triassina oberhauseri* (Gazdzicki and Reid, 1983) and the problematicum *Microtubus communis* Flügel (Reid, 1989).
Pilot Mtn. Subdivision	60°52'00"N 135°13'11" W	(Canada) NTS 105 D/14	Linear, 10m wide slightly silicified massive limestone	Early Norian based on corals
Emerald Lake	60°15'44"N 134°45'28" W	(Canada) NTS 105 D/7	Massive fossiliferous limestone, forms the east limb of a north striking anticline, bed dips 45° E	Norian based on the conodont *E. englandi* (S. Zhang, pers. comm., 1999) and corals.
Canyon (Gray) Mtn.	60°39'25"N 134°53'20" W	(Canada) NTS 105 D/10	Massive, black to gray-weathering massive recrystallized limestone	Norian based on *Wallowaconcha reylenea.*
Upper Cap Creek	60°51'19"N 134°41'45" W	(Canada) NTS 105 D/15	Dark gray, massive limestone with mudstone beds containing *Monotis* sp.	Early to Late Norian based on corals, the bivalve *Monotis* and the conodont *E. bidentata*.
Long Creek	63°12'17"N 149°42'11" W	(USA) USGS Healey A-6 quadrangle	Massive, gray saccharoidal limestone in stream cut and a few meters to the NW	Norian based on corals and the brachiopod *Spondylospira lewesensis.*

prepared and examined. Thin sections and polished slabs were inspected and photographed under reflected light, using a Leica binocular microscope with a Minolta camera attachment. Black and white photographs used in the analysis were taken using a Minolta camera mounted on a copy stand, and the remaining material was observed by the unaided eye. The material was cataloged and curated in the University of Montana Invertebrate Paleontology (UMIP) collections repository.

Preservation of the scleractinian corals is generally good, however, in all specimens, the original aragonite skeleton is replaced by calcite. Some material was too poorly preserved and thus was excluded in the analysis. The calcite recrystallization does not preserve the fine coral microstructure, therefore microstructure analysis (Roniewicz, 1989) was not possible. As a result, coral were identified by traditional methods based on external and internal morphology. Morphologic features observed and measured include: colony form, angle of corallite bifurcation, type of columella, corallite shape and diameter, distance between corallite centers, number of septa and septa systems, septa size and appearance, presence of dissepiments, and presence of granules. Coral identifications were made based mainly upon descriptions and methods of Roniewicz (1989). The systematic paleontology of the coral follows the general convention of *The International Code of Zoological Nomenclature* (Ride et al., 1985) and the guidelines set by the *Journal of Paleontology*.

Statistical Methods

Coral species lists for one Siberian terrane and nine North American displaced terranes were compiled using information provided by Melnikova and Bychkov (1986), Schlichtholz (1997), Goodwin (1999), and data derived from this study. The list was incorporated into a data matrix in which the numbers “1” symbolize presence of a species and “0” symbolize absence. The data matrix was then used in the following three statistical analyses: 1.) the probabilistic faunal similarity analysis (RCSI) of Raup and Crick (1979), 2.) calculation of a Jaccard similarity matrix and cluster analysis using the unweighted pair-group method using arithmetic averages (UPGMA) algorithm of the program, MVSP v.2.1 (Kovach, 1993), and 3.) parsimony analysis of endemicity (PAE) using the program, PAUP v.30.s (Swofford, 1991)[1]. Faunal data from the Siberian terrane were included in the analyses in order to test the North American – Siberian connection hypothesis. Analysis was performed following similar approaches taken by Belasky and Runnegar (1994), Hanger (1996), and Yarnell et al. (1997). Statistical methods are given on page 98 and Table 3.

Results from each analysis are presented, compared, and used to reconstruct Triassic terrane paleogeography. Final interpretations of terrane paleogeography were made and incorporated into a new map of the Triassic paleogeography of western North America. To give further support to the interpretation, the Triassic

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[1] See Shi (1993) for a complete review of the use of multivariate statistics (cluster analysis) in paleontology; refer to the methods discussed in Raup and Crick (1979) for probabilistic similarity analysis; and see Rosen (1992) for a discussion on PAE.

map was compared with other established paleogeographic information for Permian and Jurassic times (see page 106 for more discussion).

CHAPTER III

GEOLOGIC SETTING

Throughout the Cordillera from Alaska to Mexico, occur fossil carbonate deposits and reefs, collectively termed “buildups” (Stanley, 1979) that are rich in tropical fossils including algae, foraminifers, sponges, spongiomorphs, scleractinian corals, molluscs, and echinoderms. These buildups are now part of the North American terrane collage making up the Cordillera. The terrane amalgamation phenomenon resulted from the Early Jurassic through Cretaceous tectonic displacement and accretion of volcanic island arcs that formed along the stable western margin of North America (Jones et al., 1982). Coral-dominated carbonate buildups, probably similar to those known today (Stanley, 1996), rimmed the islands and developed along the coast. These buildups bear only passing resemblance to the thicker, better-developed carbonate complexes and reefs formed within the ancient Tethys Sea. Examples from Cordilleran terranes differ from Tethyan counterparts in their smaller scale and the fact that they were deposited on tectonically active margins of the continent or in volcanic arc settings where carbonate accumulation was controlled by climate, subsidence, and volcanic sedimentation (Stanley, 1996; Flügel and Stanley, 1984).

Triassic carbonates and the North American Cordillera: a brief overview of their evolution

The beginning of the Triassic period (≈250 Ma) marks the transition between the catastrophic end-Permian mass extinction and the eventual dramatic global rejuvenation of reefs during the Middle to Late Triassic. Considered the greatest of all mass extinctions, the Permo-Triassic event, coupled with drastic climate changes and a marked eustatic sea-level fall (Haq et al., 1987), devastated most genera and families of plants and animals. For five to ten million years of the Early Triassic, all reefs and many of their inhabitants apparently disappeared (Stanley, 1987). Diverse tropical Early Triassic life seems to have vanished from the fossil record until Middle Triassic time, when tropical environments reappeared and ultimately reestablished reef communities that had flourished in Permian time. However, the foundation of Mesozoic reef communities was different from that of the Permian.

The major organisms that thrived after the Permo-Triassic included algae, calcareous sponges, and a new coral group embodying the ancestors of all modern coral, the scleractinians. Following an adaptive radiation, these early corals rapidly increased and diversified, until the Late Triassic, when they had become the principal reef-builders. Eventually, in the Jurassic, scleractinian corals permanently established their dominance on reefs and today maintain this dominance.

The best record of Mesozoic reef activity occurred in the former Tethys region, found today in the following countries of west-central Europe: Germany, Austria, Northern Italy, Greece, and Slovenia. By the Middle Triassic, carbonate deposition had resumed after the lengthy reef eclipse, and large, extensive carbonate platforms took shape throughout the tropical to subtropical expanse of the Tethys Seaway. Eventually, during the Middle to Late Triassic, Paleozoic-like survivors, or possible Permian Lazarus taxa, joined scleractinian corals to build the impressive Tethyan reef structures of Europe and Eurasia (Stanley, 1997). Stanley (1988) first mentioned the idea that Lazarus taxa from the Permian actually may have populated Middle Triassic Tethyan reefs. Flügel (1994) revised this idea after extensive study of Tethyan fauna revealed little similarity to Permian organisms. However, discovery of holdover taxa in North American Cordilleran terranes such as Permian phylloid algae at Lime Peak, Yukon (Reid, 1986) suggests the terranes may have served as refugia for Permian taxa during the Early Triassic reef eclipse. These terrane refuges may have then "assured survival of some Tethyan biotas which subsequently repopulated the Tethys after the recovery interval" (Stanley, 1997, p. 1658).

At the same time corals were recovering and gaining a strong foothold in the Tethyan reef community, similar reefs were forming along volcanic island arcs in the Paleo-Pacific Ocean, outwards from the western margin of North America. The North American reefs and reef buildups contained a tropical faunal assemblage, both unique and typical of the Triassic, and are found today scattered in and among displaced terranes. These reef deposits serve as windows to an ancient world where tropical island chains arched across portions of the Paleo-Pacific while tectonic processes were at play transforming the surface of the Earth and piecing it together like a giant jigsaw puzzle.

Starting at the end of the Late Triassic, the last major episode of continental growth began in North America. An entire section of continent encompassing regions of Mexico in the south, to the end of Alaska in the north, and extending inland almost 500 kilometers, began to assemble from blocks of land (terranes) consisting of islands, plateaus, ridges, island arcs, and even fragments of other continents. These terranes rode on top of tectonically active oceanic plates that were being pulled and subducted underneath the preexisting craton. Over time, throughout the Jurassic to Cretaceous, each individual terrane moved along in conveyor-belt fashion and eventually docked or accreted to the western margin of North America. After accretion, many terranes were cut by shear faults, deformed into strips of land parallel to the continental margin, or tectonically rotated. Together they form the western North America Cordillera, a collage of about 200 known exotic terranes that differ in geology, paleontology, and paleomagnetic properties.

Geologists have studied many of these terranes in detail, yet there remains controversy over whether the terranes formed close to North America, or originated far out in the Paleo-Pacific Ocean. At the center of this controversy is the unexplained occurrence of Tethyan fossils in North and South America. Stanley (1994a) discussed five hypothetical mechanisms to account for the transport of Tethyan faunas across the Paleo-Pacific. These mechanisms include: 1) “long-range trans-Pacific dispersal of larvae”, transport by paleoceanic currents of larvae from Tethyan fauna across the Pacific, 2) “volcanic island stepping stones”, immigration of Tethyan fauna along island chains, 3) “beached funeral Viking ships”, tectonic transport of terranes carrying fossils, 4) “Noah’s arks”, tectonic transport of terranes carrying living faunas, and 5) “ the Hispanic Corridor”, dispersal of faunas through a marine passageway linking western Tethys through Pangea to the western Paleo-Pacific of western North America. It is possible that more than one mechanism will explain the occurrence of Tethyan fossils in the Americas, therefore continued study of terrane paleontology is important. The two fossil localities examined in this thesis, Lime Peak, Yukon, and Long Creek, Alaska, occur within two major displaced terranes of North America, the Stikine and Chulitna terranes. Both localities are significant in that they contain rich fossil assemblages that may reveal connections shared between Cordilleran terranes and thus provide insight into their evolution.

Lime Peak

Lime Peak is a massive limestone reef complex located in southern Yukon, within one of the largest Cordilleran displaced terranes, Stikine terrane (Fig. 1). Stikine terrane forms the majority of the Intermontane Belt, one of the five morphophysiographic belts of the Canadian Cordillera (Fig. 5). The reef complex occurs in an arc marginal basin of Early Mesozoic sediments known as the Whitehorse Trough. Its carbonate-dominated deposits form Lime Peak, a mountain located approximately 40 km northeast of Whitehorse, at the southeast end of Lake Laberge, on the north side of Thomas Lake (Fig. 6). Lime Peak and

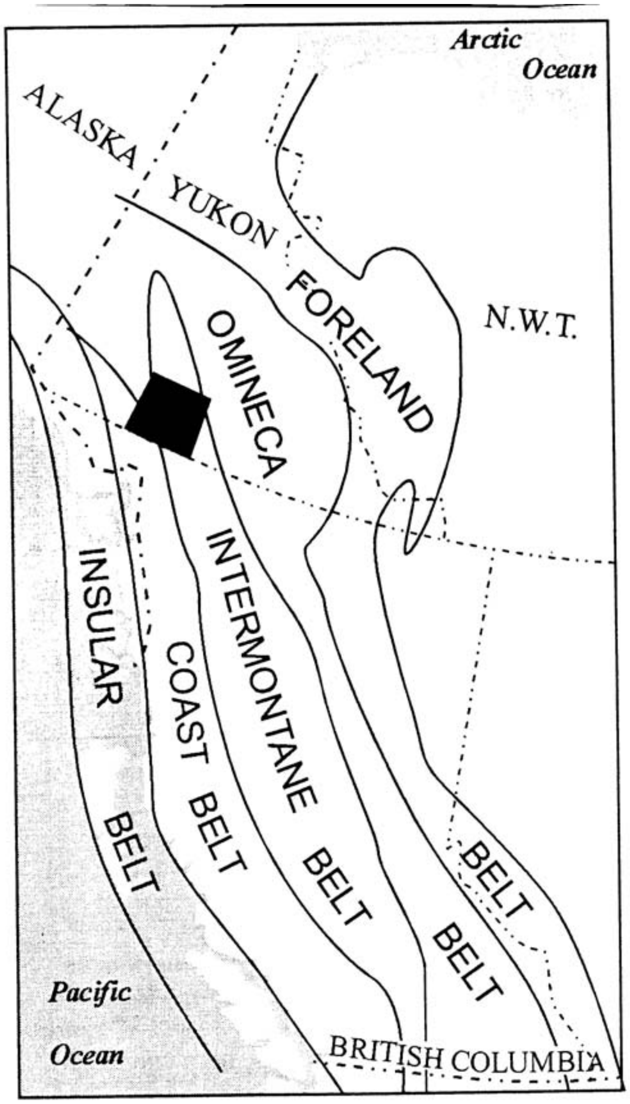


Figure 5. Map showing the five morphophysiographic belts of the Canadian Cordillera. The black box represents Whitehorse map sheet NTS 105D and indicates a portion of the Stikine terrane (from Hart, 1997).

the volcanic and sedimentary deposits of the Whitehorse Trough constitute the northern portion of both Stikinia and the Intermontane Belt.

Stikine terrane is composed of a Paleozoic, poly-metamorphosed basement known as the Stikine Assemblage. In Yukon, the Takhini Assemblage is a Paleozoic meta-volcano-sedimentary package correlative with the Stikine Assemblage and it marks the most northerly occurrence (Figs. 7 and 8) (Hart,1997). Lying above the Takhini Assemblage and separated by an unconformity, occurs the Middle Triassic Joe Mountain Formation. This unit is comprised of a nearly contiguous succession of mafic volcanic rocks and their intrusive equivalents (Hart, 1997). These rocks have no known Cordilleran correlatives and, as the oldest arc related rocks in the Whitehorse Trough, likely form the basement to younger rocks of Stikinia (Hart, 1997).

Continuing up stratigraphic section, an uncertain boundary delineates the base of the Lewes River Group (Cairnes, 1938; Tozer, 1958). The Lewes River Group is characterized by a succession of volcanic and sedimentary rocks, and records the initial deposition of arc sediments within the Whitehorse Trough (Fig. 8). The lowest stratigraphic unit within the group is the early Upper Triassic Povas Formation. Although poorly defined, it consists of two augite-phyric and aphyric rock members. Above this unit begins the Whitehorse Trough Supergroup, a sedimentary package divided into the Triassic Aksala Formation and the Jurassic Laberge Group. These two units are separated along the western margin of the basin by an erosional disconformity (Hart, 1997). The succession of rocks in the Whitehorse Trough record the presence of a volcanic

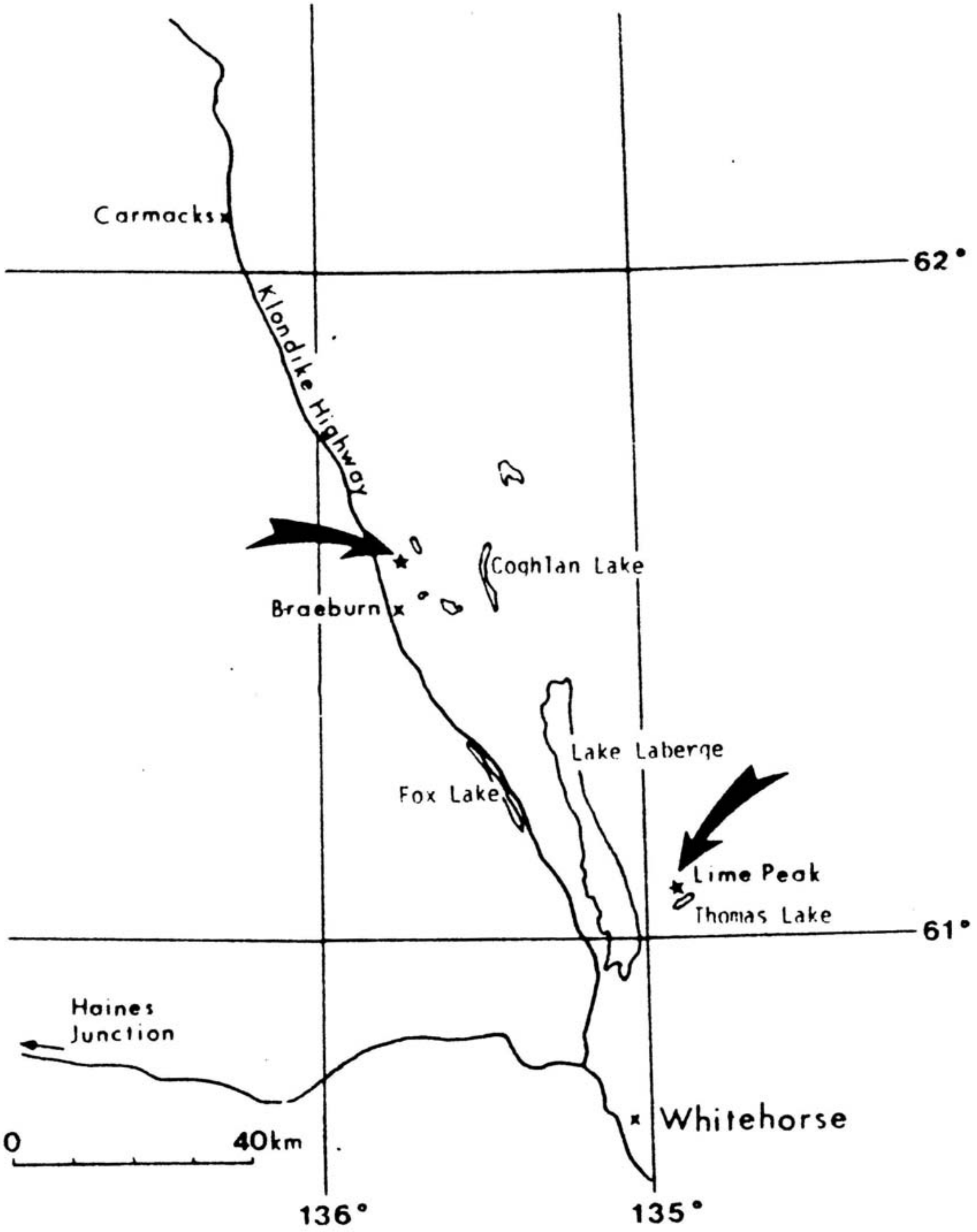


Figure 6. Map showing the general location of Lime Peak (from Senowbari-Daryan and Reid, 1987).

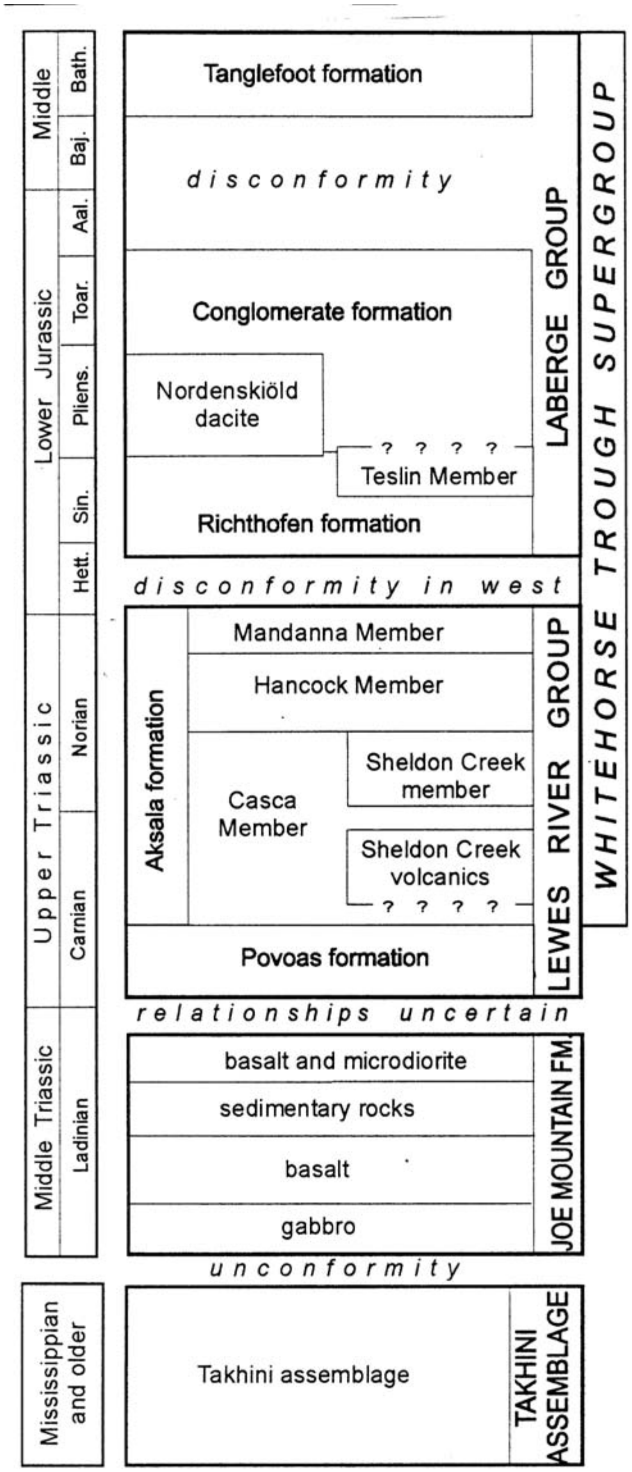


Figure 7. Temporal distribution and stratigraphic relationships of the units constituting northern Stikine terrane (Hart, 1997).

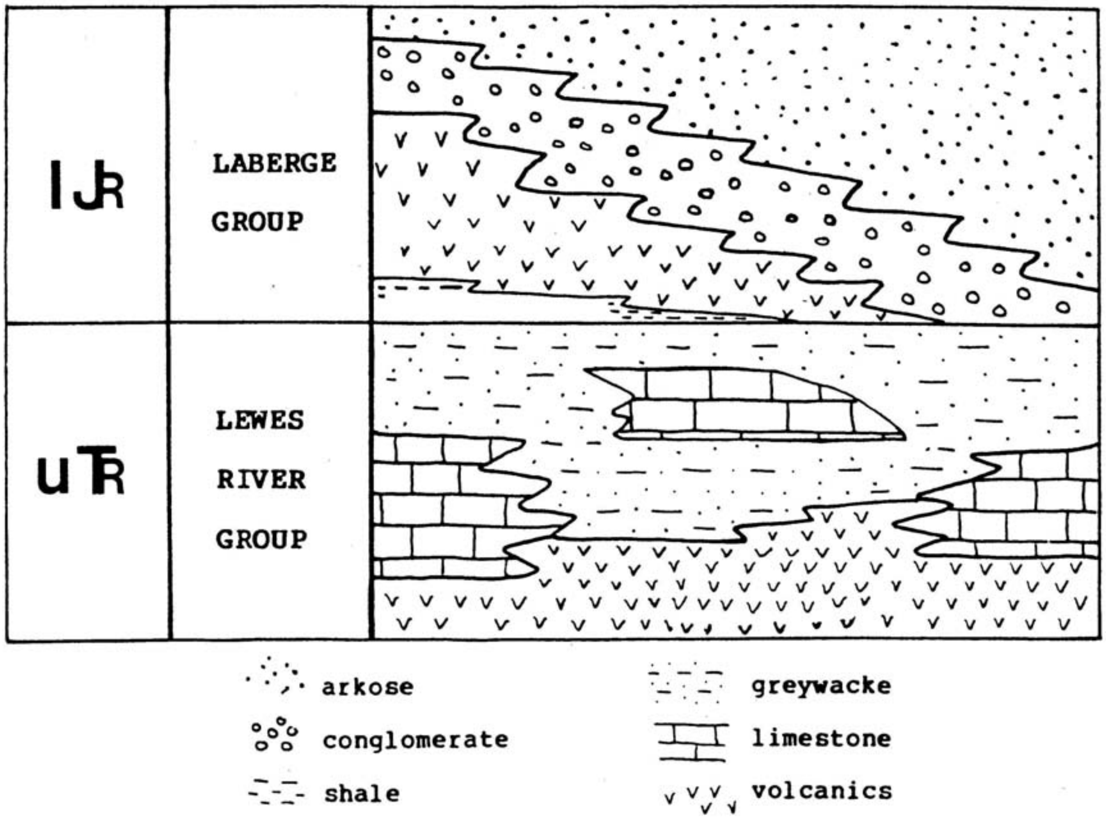


Figure 8. Stratigraphy of the Whitehorse Trough (from Reid and Tempelman-Kluit, 1987).

island-arc basin which formed in response to a west-dipping subduction zone and was accreted to North America during Middle Jurassic time (Reid and Tempelman-Kluit, 1987). Figure 9 depicts the likely depositional environment for the Whitehorse Trough.

The ancient volcanic island-arc reef deposits at Lime Peak belong to a stratigraphic unit in the upper portion of the Aksala Formation, the Hancock Member. The Hancock Member is characterized by thick units of massive carbonate and is dated as Upper Norian by conodonts, micro- , and macrofossils (England, 1980; Gadzicki and Reid, 1983; Senowbari-Daryan and Reid, 1987). Dominated by limestone and limy siltstone, the Hancock Member shows depositional variation across the width of the Whitehorse Trough (Fig. 10) (Hart, 1997). Carbonate beds at Lime Peak consist of reef and inter-reef limestones, typical of those found in the central facies belt of the Trough (Hart, 1997).

The Lime Peak reef complex lies within the Laberge map sheet (Canadian NTS 105E, 61°04’08”N, 134°53’57”W) is about 250 m thick, extends 3 km east-west, and 2.5 km to the north (Fig. 11) (Reid, 1985). It overlies and makes fault contact with Lewes River volcanics. Carbonate deposition at Lime Peak occurred in a period of quiescence in volcanic and siliciclastic sedimentation. During this time, pioneering organisms such as spongiomorphs, calcisponges, scleractinian corals, and calcareous algae diversified and built a series of patch reefs and inter-reef limestone deposits (Tempelman-Kluit, 1978; Reid, 1985; Reid and Tempelman-Kluit, 1987). Today, the deposits are represented by reef

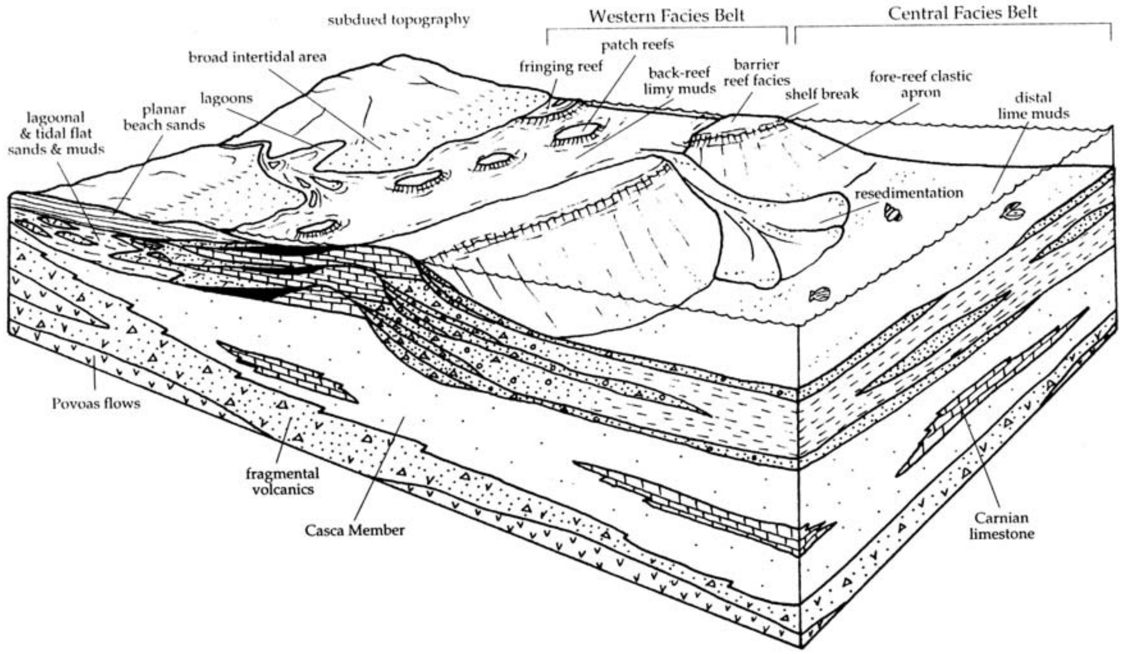


Figure 9. Probable depositional environment for the Whitehorse Trough during the Late Triassic (from Hart, 1997).

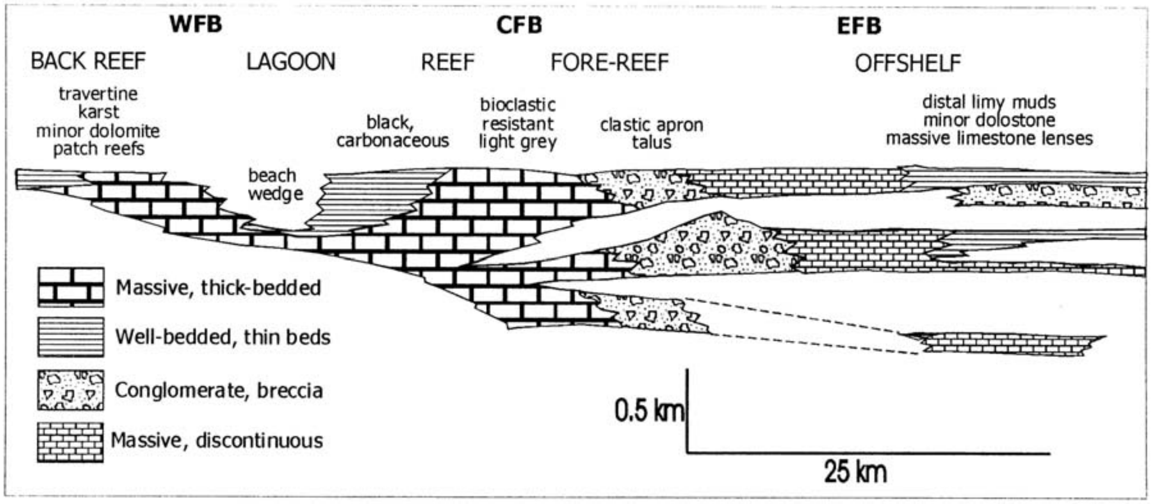


Figure 10. Schematic representation of the facies and distribution of the Hancock member carbonate rocks across the Whitehorse Trough. WFB = Western Facies Belt, CFB = Central Facies Belt, EFB = Eastern Facies Belt (from Hart, 1997).

Figure 11. Aerial photograph, looking north, of Lime Peak and Thomas Lake.

and bedded, inter-reef deposits. The carbonates are present as tabular bodies with local sponge-coral framework, about 30 m thick, skeletal sediment reefs about 100 m thick, and inter-reef limestones composed of coral thickets and reef debris (Reid and Tempelman-Kluit, 1987). Microfossils including the foraminifer *Triassina oberhauseri* (Gadzicki and Reid, 1983) and *Microtubus communis* Flügel (Reid, 1989), as well as macrofossils such as the brachiopod, *Spondylospira lewesensis* and scleractinian corals (Reid, 1985) date the Lime Peak carbonate deposits as Early to Late Norian. The Lime Peak reef complex, based on thorough sedimentological and paleontological study, is considered the best developed Triassic reef deposit in North America and is compared with classic Norian and Rhaetian Alpine reefs, of the Tethys (Reid and Templeman-Kluit, 1987).

Long Creek

The Triassic reef limestone deposits at Long Creek are only a small portion of the Paleozoic and Mesozoic rock accumulations that occur within the displaced Chulitna terrane (Fig. 1). Thought to have accreted to North America near late Early Cretaceous time when it was trapped between the Wrangellia-Peninsular-Alexander amalgam terrane and the Yukon-Tanana terrane, Chulitna is a small, distinct, terrane only several tens of kilometers long, with few known correlations in the Cordillera (Coney et al., 1980). Chulitna terrane is located in south-central Alaska, on the south flank of the Alaska Range, southwest of Cantwell in an area known as the Upper Chulitna District (Figs. 4 and 12). The Upper Chulitna District makes up the northern section of the Chulitna-Yenta Mineral belt which was first explored for gold, copper, arsenic, and other metallic mineral deposits (Hawley and Clark, 1974).

A series of Paleozoic and Mesozoic volcanic, volcaniclastic, and sedimentary rocks characterize the Chulitna terrane (Fig. 13). These rocks generally record two transgressive-regressive successions beginning with basal volcanic rocks, chert, and tuff. These units range in age from Late Devonian to Mississippian. Overlying the Late Devonian ophiolite basement is a deepening upward sequence of Pennsylvanian and Permian volcaniclastic conglomerates, sandstones, and siltstones that record terrestrial to shallow marine water deposition in proximity to a volcanic source (Whalen et al., 1999). Deep water pelagic and turbiditic deposits follow, including cherts, and thin bedded sandstones and siltstones with graded beds, basal scours, and *Chondrites* and *Scalarituba*, both neritic realm trace fossils (Whalen et al., 1999). Completing this transgressive-regressive package are Permian limestones and Permian to Triassic volcanic flows, sills, tuffs, and volcaniclastic redbeds. The Permian limestones contain a fauna of brachiopods, bryozoans, and rugose coral, indicating cool water and deposition during a time of subdued volcanic activity.

The beginning of the second transgression lies conformably below a Late Triassic redbed unit that contains quartzose clasts, suggesting proximity to a continental landmass at the time of deposition. Brown calcareous sandstone, argillite, and limestone mark the second transgression interval. The limestone, or “carbonate interval” unit in this sequence contains fossils that are a main focus of this thesis (Fig. 14). It is 15 – 20 m thick and was first dated as Upper Triassic

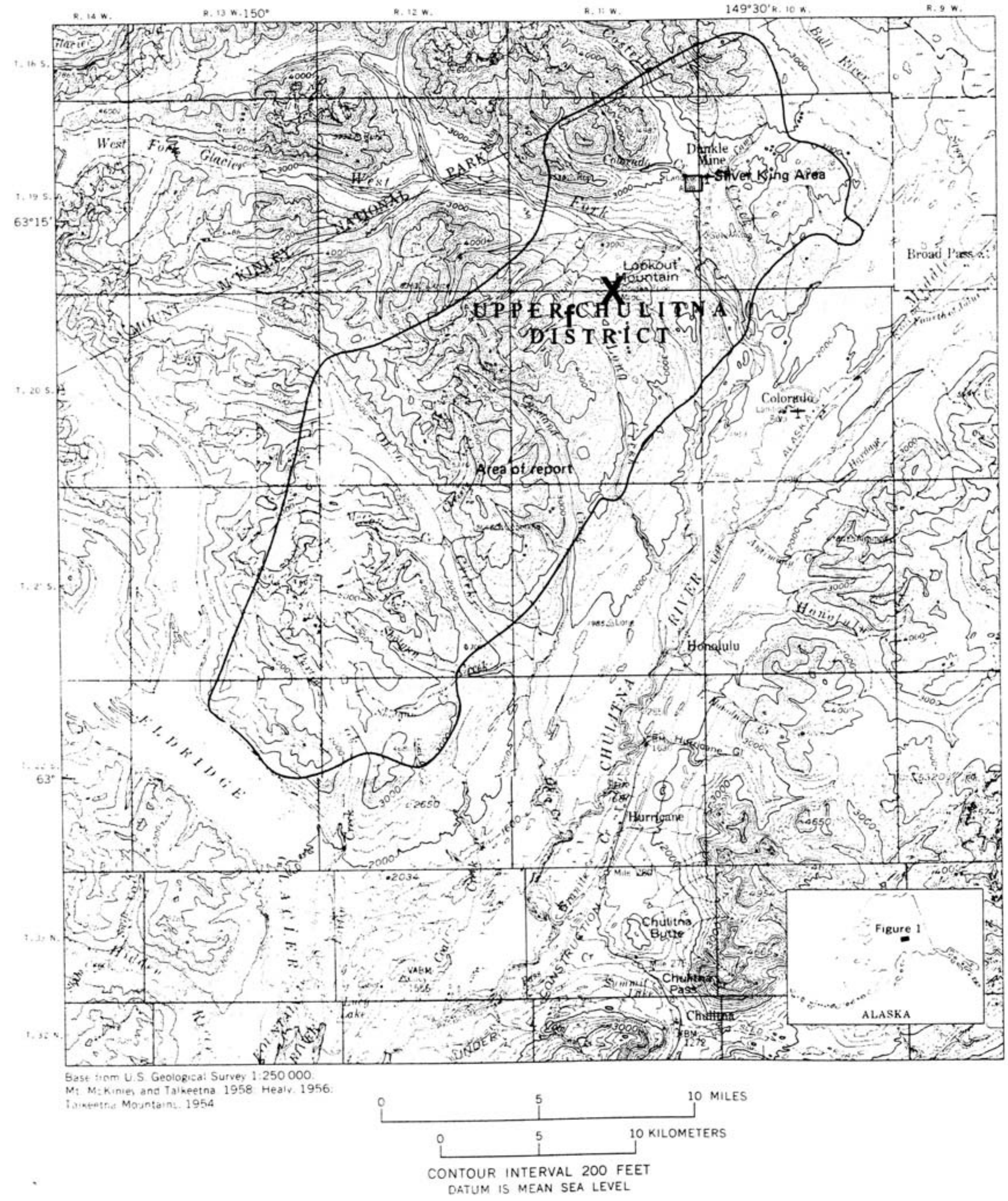


Figure 12. Map showing the extent of the Upper Chulitna district. The "X" marks the location of the Golden Zone Mine and the "f" denotes the fossil locality sampled in this report (modified from Hawley and Clark, 1974).

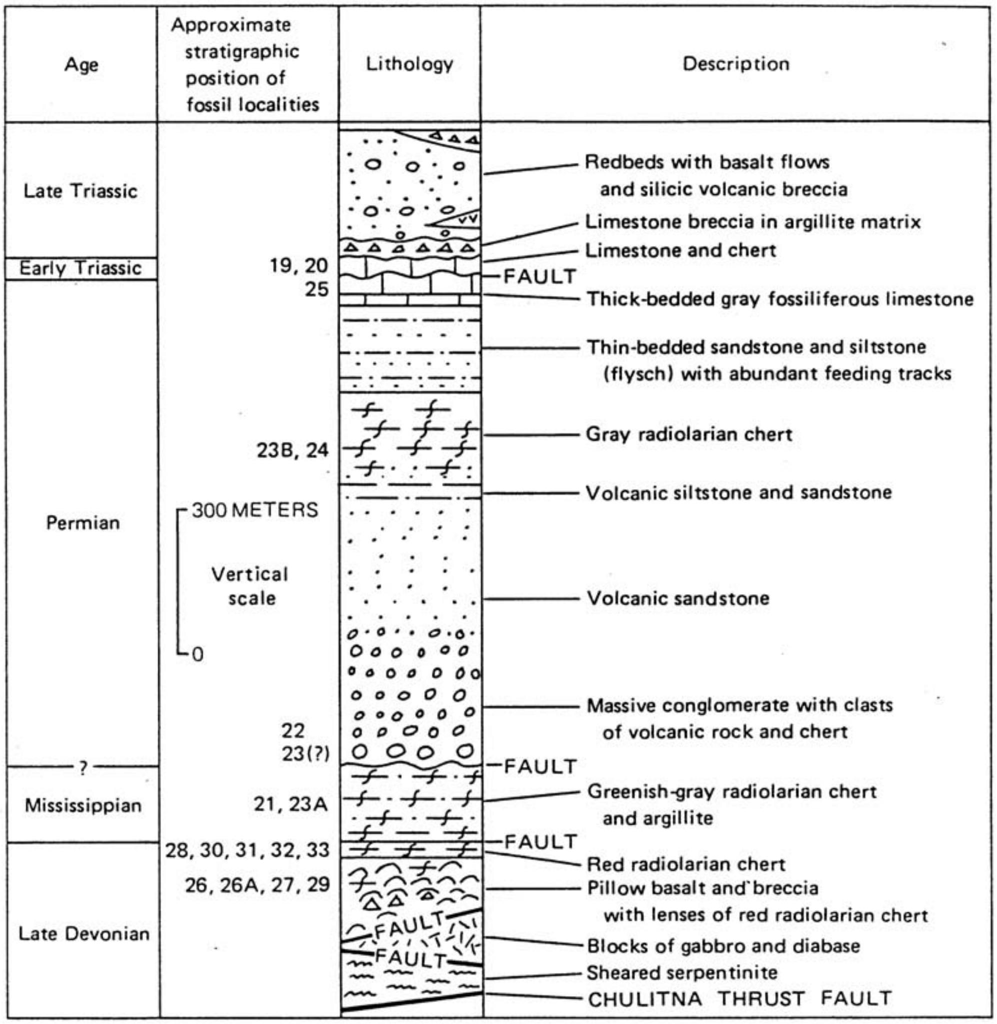


Figure 13. General stratigraphic sequence of northeast Chulitna terrane (from Jones et al., 1980).

based on bivalves and brachiopods examined by Ross (1933). According to Whalen (1999), it is generally composed of shelf margin and upper slope deposits topped by muddy biostromal to biohermal beds and patches of laminar or branching spongiomorphs, scleractinian corals, brachiopods, bivalves, molluscs, (Blodgett and Clautice, 1999*)* and large, newly discovered wallowaconchid bivalves similar to those known from Sonora, Mexico (Stanley et al., 1994). The reefal limestone beds outcrop in the stream exposure along Long Creek (USGS Healy A-6 Quadrangle, 63°12’17”N, 149°42’11”W) and at an area located just a few meters northeast of the creek, along the strike of the limestone beds (Figs. 15 and 16). This location is found about two kilometers west of the Golden Zone Mine in an area that has undergone tectonic folding and thrusting caused during terrane accretion.

The uppermost part of the Triassic unit is composed of interbedded limestone, pillow basalts, tuff, and volcaniclastics. These deposits seem to be laterally equivalent with interlayered limestone and sandstone that crops out in the northeastern part of Chulitna (Whalen et al., 1999). This sequence represents maximum shoaling and defines the transition into a final marine regression. Finally, above the Triassic limestone-basalt unit lies a sequence, thousands of feet thick, of dark fine- to coarse-grained detrital rocks. Early Cretaceous bivalves and stratigraphic correlation with a Jurassic argillite-graywacke to the south indicate a Jurassic to Cretaceous age for the unit (Hawley and Clark, 1974). Structurally deformed in many places into northeast-

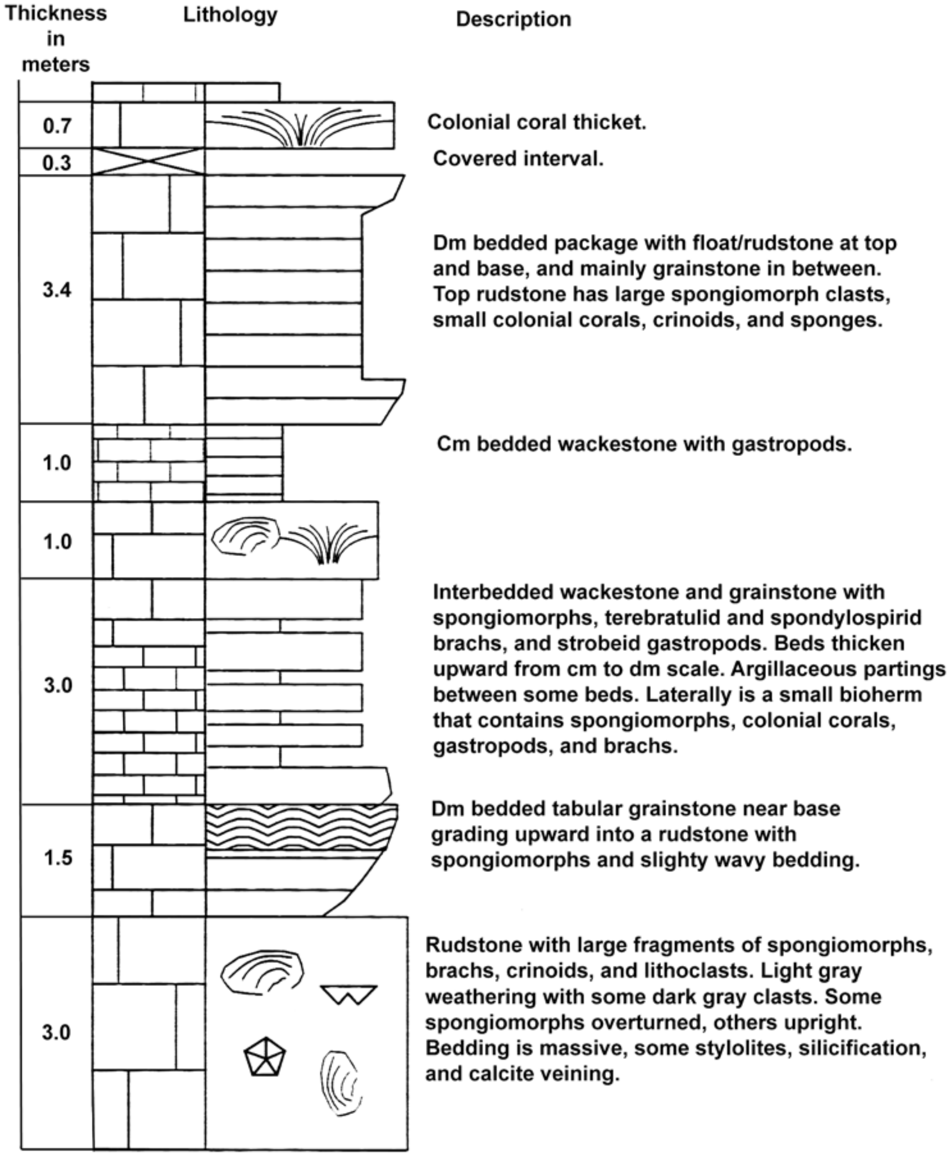


Figure 14. Stratigraphic column of the Norian deposits at Long Creek (from Whalen et al., 1999).

Figure 15. Photograph looking down the axis of Long Creek, Alaska. Rocks seen in outcrop are the Norian deposits.

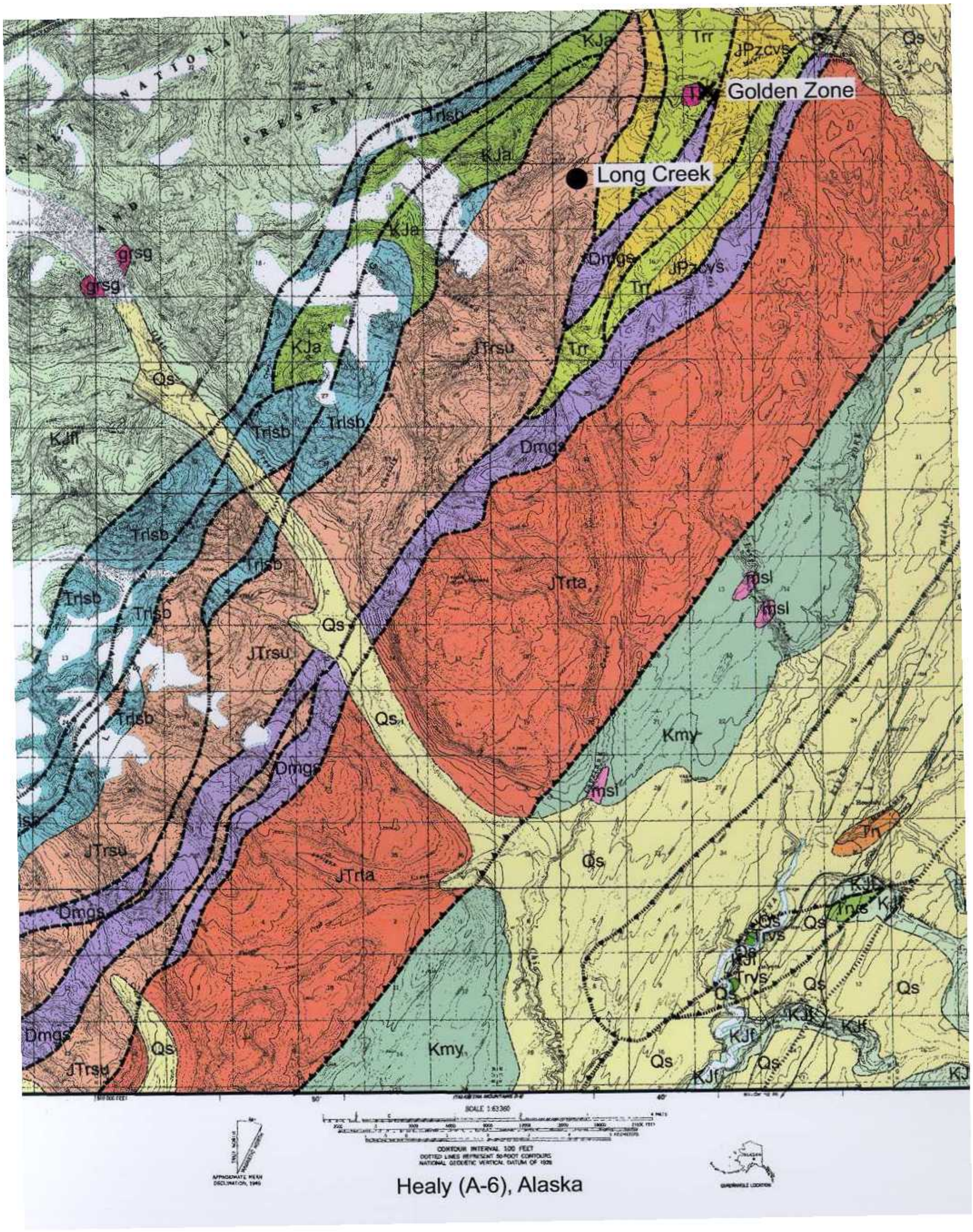


Figure 16. Geologic map showing the location of the Long Creek sample locality in Chulitna terrane. The locality occurs in JTRsu, an Early Jurassic to Late Triassic sedimentary unit.

trending folds, this unit records the tectonic accretion of the Chulitna terrane onto the western margin of North America.

CHAPTER IV

PALEONTOLOGY

Overview of fauna

Although this chapter describes primarily the coral faunas from Lime Peak, Yukon and Long Creek, Alaska, other fossils have been recovered from the areas that are also important to note. The systematic determinations for all corals were performed by the author.

***Lime Peak*.** Although this area has been mapped thoroughly (Tempelman-Kluit, 1978; Hart, 1997) and the sedimentology studied in great detail by Reid (1985), the paleontology of the deposits at Lime Peak and its correlative limestone units is only partially known. As a result of Reid's work, a few critical papers concerning the sponge and microfossil fauna of Lime Peak were generated (Gadzicki and Reid, 1983; Reid, 1986; Senowbari-Daryan and Reid, 1986). From carbonate rocks of the Late Triassic Hancock member at Lime Peak and surrounding areas, Reid, her collaborators, and others (i.e. see Hart, 1997) reported the following taxa:

<u>Calcareous sponges</u>:
- *Nevadathalamia cylindrica cylindrica*
- *Nevadathalamia* cf. *N. cylindrica*
- *Nevadathalamia ramosa*
- *Nevadathalamia norica*
- *Nevadathalamia* sp. 1
- *Cinnabaria expansum*
- *Paradeningeria alpina*
- *Distyocoelia* cf. *D. manon*
- *Cryptocoelia zitteli*
- *Colospongia dubia*
- *Colospongia bimuralis*
- *Colospongia* cf. *C. mennulensis*

Salzburgia? sp.
Henricellum cf. *H. insigne*
Follicatena irregularis
Uvanella ? irregularis
Yukonella rigbyi

Bivalves:
Pecten yukonensis
Monotis subcircularis

Brachiopods:
Spondylospira lewesensis

Spongiomorphs:
Spongiomorpha gibbosa
Spongiomorpha ramosa

Foraminifers:
Triassina oberhauseri
Aulotortus gaschei
Aulotortus sinuosus
Aulotortus tumidus
Aulotortus sp.
? Trocholina sp.

Calcareous algae:
Ivanovia sp.
Indeterminate “phylloid” algae

New identifications (this study):

Scleractinian corals:
Astraeomorpha sonorensis
Chondrocoenia schafhaeutli
Chondrocoenia waltheri
Crassistella juvavica
Distichoflabellum sp.
Distichomeandra austriaca
Gablonzeria profunda
Procyclolites triadicus
Retiophyllia oppeli
Retiophyllia norica
Retiophyllia cf. *R. robusta*

Alatoform bivalves:
Wallowaconcha cf. *W. raylenea*

The coral species list generated by the present study introduces previously undescribed and unstudied coral fauna from the Lime Peak reef complex and other local correlative limestone outcrops. Most of the coral fossils examined in this study were collected during fieldwork or obtained from Dr. Pamela Reid through a loan made to the UM collections. Reid (1985) mentioned many of these corals, but never studied them critically. A total of eleven coral species, mainly from the Lime Peak reef deposits, and one unique, newly described bivalve are here reported for the first time from Lime Peak and the Hancock Member limestone.

Long Creek. The paleontology of the limestone at the site of Long Creek and the accompanying Chulitna terrane is relatively unknown. Smith (1927) first described and illustrated a Late Triassic gastropod and bivalve species from the Chulitna terrane, followed by Nichols and Silberling (1979) who reported on a fauna of 13 species of Early Triassic (Smithian) ammoniods and noted their similarity to those found at lower present latitudes. Hawley and Clark (1974) and Jones et al. (1980) provided detailed faunal lists of Chulitna terrane, and Hoover (1991) reported the presence of the Late Triassic cyrtinoid brachiopod, *Spondylospira lewesensis* Lees, a species endemic to a number of inboard terranes of North America. Recently, Blodgett and Clautice (1999) compiled the most up-to-date report of fossil localities in the Chulitna terrane. The following is a faunal list of Triassic macro-fossils cited from the Chulitna terrane. This list was generated from Csejtey et al. (1992) and the citations mentioned above.

Ammonoids:
(Early Triassic)
- *Dieneroceras* cf. *D. knechti*
- *Euflemingites* sp. indet.
- *Prosphingites* cf. *P. slossi*
- ?*Juvenites* sp. indet.
- *Lanceolites bicarinatus*
- *Aspenites* cf. *A. acutus*
- *Arctoceras* cf. *A. bloomstrandi*
- *Wyomingites* sp. indet.
- *Xenoceltites intermontanus*
- *Meekoceras gracilitatis*
- *Wyomingites aplanatus*
- *Dieneroceras knechti*
- *Euflemingites cirratus*
- *Arctoceras tuberculatus*
- *Juvenites septentrionalis*
- *Paranannites aspenensis*
- *Owenites* cf. *O. koeneni*
- *Metussuria waageni*

(Late Triassic)
- *Hauerites* sp.
- *Indojuvavites* sp.
- *Rhacophyllites* sp.
- *Juvavites magnus*
- *Placites* sp.
- *Pseudosirenites* sp.

Bivalves:
(Early Triassic)
- “*Posidonia*” *mimer*
- Unident. aviculopectinid
- Unident. pteriid

(Late Triassic)
- *Lima blackburnei*
- *Cassianella lingulata*
- *Septocardia* sp.
- *Monotis subcircularis*
- *Mysidiopteria* sp.
- *Halobia* cf. *H. superba*

Arcestes sp.
Trophites cf. *T. kellyi*
Propaemussium sp.

Brachiopods:
(Late Triassic)
Spondylospira lewesensis
Lobothyris praepunctata
Lobothyris sp. cf. *L. monstrifer*
Fissirhynchia fissicostata
Zugmayerella koessensis
Laballa suessi

Conodonts:
(Early Triassic)
Neogondolella jubata
“Neospathodus” conservativus

(Late Triassic)
Neogondolella navicula
Epigondolella cf. *bidentata*
Metapolygnathus primitius

Gastropods:
Protorcula alaskana

Hydrozoans:
Heterastridium conglobatum

New identifications (this study):

Scleractinian corals:
Alpinophyllia flexuosa
Astraeomorpha crassisepta
Distichophyllia marmorea
Distichophyllia norica
Retiophyllia norica

Alatoform bivalves:
Wallowachocha sp.

Spongiomorphs:
Stromatomorpha cf. *S. californica*

Triassic fossils of the Chulitna terrane are known, but there is precious little knowledge on Triassic corals and hydrozoans. Based on the collections at Long Creek, the present study introduces for the first time, five newly discovered Late Triassic fossil coral taxa and one reef-adapted alatoform bivalve from the Chulitna terrane. Many of these corals occur in the Northern Calcareous Alps of Germany and Austria where they range from Norian to the Rhaetian stages.

SYSTEMATIC PALEONTOLOGY

All specimens studied in this report were either acquired from the University of Montana paleontological collections or collected during fieldwork for this thesis. Specimen numbers with the UMIP prefix are curated in the University of Montana Museum of Paleontology invertebrate collections. Specimens with numbers beginning with the letter “R” are part of a loan from Dr. Pamela Reid, The University of Miami, and are here designated as the “Reid Collection”.

The following Late Triassic coral systematic identifications are based on the founding works on European Alpine reef faunas by Reuss (1854) and Frech (1890) as well as the detailed, revolutionary monographic studies of Cuif (1965–1976) and Roniewicz (1989). Cuif revised many of the original Triassic Alpine coral classifications at the generic and familial levels in order to reflect the differences in microstructural arrangement of aragonitic coral skeletal features from post-Triassic skeletal features. Thus, traditional classification of Triassic coral on the basis of gross morphology gave way to identification based on the type of aragonite skeletal microstructure present. As a result, revised and new coral classifications have restructured Triassic coral systematics (Cuif, 1965-1976; Beauvais, 1980; Roniewicz, 1989).

Problems, however, arise when Triassic corals of North America are studied. Unlike their European counterparts, North American Triassic corals are either silicified, calcitic, or recrystallized, and so the original aragonitic microstructure is not preserved. As a result, the identifications in this thesis are made on the basis of gross morphology and comparison with descriptions and illustrations made by previous authors.

LIME PEAK, YUKON

Class ANTHOZOA

Order SCLERACTINIA Bourne, 1900

Suborder PACHYTHECALIINA Eliášová, 1976

Superfamily VOLZEIOIDEA Cuif, 1977

Family GABLONZERIIDAE Roniewicz, 1989

Genus GABLONZERIA Cuif, 1976

Type Species. – Isastraea profunda major Frech, 1890

GABLONZERIA PROFUNDA (Reuss, 1854)

(Plate 1, Figures 1 – 3)

Isastraea profunda REUSS, 1854, p. 116, Pl. 9, figs. 5, 6; FRECH, 1890, p. 21, Pl. 5, figs. 1-3a; SMITH, 1927 (part), p. 128, Pl. 105, fig. 8, Pl. 112, figs. 5, 6, Pl. 114, figs. 1-3; CUIF, 1976, p. 116, Pl. 11, figs. 1-8.

Elysastraea profunda (Reuss). SQUIRES, 1956, p. 25-26, figs. 48-51; STANLEY, 1979, Pl. 3, figs. 6, 8; KRISTAN-TOLLMANN AND TOLLMANN, 1983, Pl. 1, figs. 1-4.

Elysastraea sp. KANMERA, p. 129, Pl. 13, Fig. 11.

“Elysastraea”. REID, 1985, p. 285, fig. A15.

Pamirastraea profunda (Reuss). MELNIKOVA, 1975, Pl. 19, fig. 1.

Actinastraea (?) sp. MONTANARO GALLITELLI, RUSSO, AND FERRARI, 1979, Pl. 1, fig. 2a, b.

Gablonzeria profunda (Reuss). STANLEY, 1986, Pl. 3.1, figs. 13, 14; RONIEWICZ, 1989, p. 33, Pl. 4, fig. 1, Pl. 5, fig. 3; STANLEY AND WHALEN, 1989, p. 812, figs. 6.10, 7.11; STANLEY, 1994b, p. 82, Pl. 1, figs. 6-7.

Guembelastraea vancouverensis (Clapp and Shimer). PRINZ, 1991, p. 158, Pl. 1, fig. 6; PRINZ-GRIMM, 1995, p. 238, text-fig. 5, fig. 8g.

Material. – Five small massive cerioid colonies weathered from limestone and two lamellar colonies in a limestone matrix. Most are cut and polished or thin sectioned; UMIP 2.20067, 2.20066, 2.20070, and 2.20094; Reid Collection: R-80-8A-9, R-81-6-3 and R-81-13-5b. From the Lime Peak reef complex, southern Yukon, Stikine terrane (61º03.5'N, 134º54'W).

Description. – Microstructure absent. Specimens calcitic and recrystallized, internal preservation poor, weathered surfaces reveal some detail. Polygonal calices deep and form sharp edges, ranging in diameter from 3.3 – 5.0 mm. At least three septa cycles visible on weathered surface: S1, S2, and occasionally S3 preserved, S4 rare – incomplete systems common. S1 septa reach center and S2 septa shorter. Septal faces covered with granules, S1 number about 10, S2 number 10 – 14.

Discussion. – These specimens correspond closely with *G. profunda* described and figured by Roniewicz (1989). The coral growth form, size and appearance of calices, and septal formation fit the criteria. Although poorly preserved, the specimens are recognized on the basis of gross morphologic features first described by Reuss (1854). This species was reported from Hells Canyon, southern Wallowa Mountains, Oregon, by Stanley and Whalen (1989) on the basis of gross morphology. Prinz (1991) and Prinz-Grimm (1995) identification of *Guembelastraea vancouverensis* Clapp and Shimer is most likely *Gablonzeria profunda* (Reuss) since corallite diameter on figured specimens averages about 5.0 mm, a value larger than the 2.0 mm diameter determined by Clapp and Shimer for *G. vancouverensis.*

Occurrence. – Norian-Rhaetian, Lime Peak, southern Yukon, Canada; Gravina Island, Alaska; Lake Iliamna, Alaska; Vancouver Island (Lake Cowichan); Hells Canyon, Oregon; Lewiston (Mission Creek), Idaho; Pilot Mountains, Nevada; Lake Shasta, California; Sonora, Mexico; Peru; Chile; Zlambach beds, Austria; Pamir Mountains, U.S.S.R.; Japan.

Suborder CARYOPHYLLIINA Vaughan and Wells, 1943

Superfamily REIMANIPHYLLIOIDEA Melnikova, 1975

Family DISTICHOPHYLLIIDAE Cuif, 1977

Genus RETIOPHYLLIA Cuif, 1967

Type Species. – *Thecosmilia fenestrata* Reuss, 1854 *In* Frech, 1890, p. 9.

RETIOPHYLLIA OPPELI (Reuss, 1865)

(Plate 2, Figures 1, 2)

Calamophyllia Oppeli REUSS, 1865, p. 160, Pl. 4, fig. 1.

Thecosmilia Oppeli (Reuss). FRECH, 1890, (part), p. 10, Pl. 2, figs. 18-20, 24, Pl. 3, figs. 4 A-E (*non* Pl. 2, figs. 21-23).

Thecosmilia aff. *oppeli* (Reuss). MONTANARO GALLITELLI, RUSSO, AND FERRARI, 1979, p. 146, Pl. 4, fig. 2.

“Thecosmilia”. REID, 1985, p. 282, fig. 14b.

Retiophyllia oppeli (Reuss). STANLEY, 1986, p. 27, table 3.1; RONIEWICZ, 1989, p. 47, Pl. 9, figs. 7, 8, Pl. 10, figs. 3, 4; PRINZ, 1991, p. 157, Pl. 1, fig. 5; PRINZ-GRIMM, 1995, p. 237, fig. 8b, c. GOODWIN, *in preparation.*

Material. – Two massive colonies, slightly compressed, Reid Collection: R-81-3 and R-81-15; two colonies in growth position in limestone matrix, Reid Collection: R-80-4-6 and R-TOR-79-6-1-1; one specimen of coral debris in limestone matrix, UMIP 2.20107; all from Lime Peak reef complex, southern Yukon, Stikine Terrane (61º03.5’N, 134º54’W). One colony, slightly silicified and compressed from Pilot Mountain Subdivision, UMIP 2.25408, Whitehorse area, Yukon, Stikine terrane (60º52'00'N, 135º13'11"W).

Description. – Colonies phaceloid, with frequent and narrow lateral connecting processes. Connection also by fusion of corallites. Bifurcation frequent at acute angles. Corallites oval in cross section (sometimes angular), with strongly fusiform and highly granulated septa. Corallite diameter: 3.5 – 4.0 mm, septa average 40. Four septal orders: S1 septa thickest and longest; S2 septa strong, subequal in length to S1; S3 septa about 2/3 the length of S1; S4 septa thin and about 1/3 the length of S1. Relatively thin pellicular wall. Dissepiments present, but poorly preserved.

Discussion. – The specimens are all poorly preserved and most appear slightly deformed. Recrystallization makes identification difficult, however, observed characteristics match well with those described by Roniewicz (1989). These specimens resemble *R. gracilis* Roniewicz in corallite diameter and number of septa, but differ in the thickness of S1 septa, abundance of granules, thinner pellicular wall, and thin connecting processes.

Occurrence. – Norian-Rhaetian, Lime Peak, southern Yukon, Canada; Wrangell Mountains; Hells Canyon, Oregon; Sonora, Mexico; northern Chile; Northern Calcareous Alps, Austria; Indonesia.

RETIOPHYLLIA NORICA (Frech, 1890)

(Plate 2, Figures 4, 5)

Thecosmilia norica FRECH, 1890, p. 9, Pl. 1, figs. 14-24.

Thecosmilia norica var. *densisepta* HAAS, 1909, p. 145, Pl. 5, fig. 3.

Thecosmilia norica var. *lobatisepta* HAAS, 1909, p. 145, Pl. 5, fig. 4.

Paradistichophyllum noricum (Frech). MELNIKOVA, 1975, p. 90, Pl. 15, figs. 3, 4.

“Thecosmilia” cf. *“T.” fenestrata* (Reuss). STANLEY, 1979, p. 56, Pl. 3, fig. 1.

“Thecosmilia”. REID, 1985, p. 282, fig. 14c.

Retiophyllia norica (Frech). RONIEWICZ, 1989, p. 52, Pl. 8, figs. 5-8, Pl. 9, fig. 2, Pl. 14, figs. 1, 2; STANLEY, In Stanley et al., 1994, p. 12, figs. 10.1, 10.2.

Material. – One specimen of coral fragments in limestone matrix, thin sectioned, and one specimen of coral colony in growth position; UMIP 2.20059 and Reid Collection: Fig. 14c (R-80-LP). From Lime Peak reef complex, southern Yukon, Stikine terrane (61º03.5'N, 134º54'W).

Description. – Corallite diameter: 10 – 15 mm, folds on corallite surface. Pellicular wall thin, costae visible. Septa fusiform, in 3 – 4 orders: S1 septa thickest and reach center; S2 septa slightly shorter, thinner than S1; S3 septa about ½ the length of S1; S4 septa rudimentary or poorly preserved, reach ¼ the length of S1. Septa number 50 – 76. Lateral, upward spinal projections on corallite surface. Dissepiments thin, vesicular, and subhorizontal; incorporated into septal structure at axis. Microstructure absent.

Discussion. – The specimens are calcitic and highly recrystallized, and show little interpretive detail. Specimen R-80-LP is well preserved, however corallites seem to bifurcate at acute angles. It is possible the specimen has undergone compaction either from soft sediment deformation or tectonic movement. Due to the poor nature of preservation, only limited gross morphology was available for identification.

Occurrence. – Norian-Rhaetian, Lime Peak, southern Yukon, Canada; Long Creek, Alaska; Sonora, Mexico; Pilot Mountains, Nevada; Zlambach beds, Austria.

RETIOPHYLLIA cf. R. ROBUSTA Roniewicz, 1989

(Plate 2, Figure 3)

Thecosmilia norica FRECH, 1890, Pl. 10, fig. 6.

Retiophyllia robusta RONIEWICZ, 1989, p. 52, Pl. 8, figs. 1, 3, 10.

Material. – Two specimens of coral fragments in a black limestone matrix; UMIP 2.20060 and Reid Collection: R-80-14-1A. From Lime Peak reef complex, southern Yukon, Stikine terrane (61º03.5'N, 134º54'W).

Description. – Corallite diameter: 15 – 20 mm. Pellicular wall thin, costae visible, granules present. Septa in at least 3 orders, fusiform: S1 septa thickest, club shaped and reach center; S2 septa slightly shorter and thinner than S1; S3 septa about ¼ the length of S1, rudimentary or poorly preserved in most specimens. Septa number 48 – 52. Variable dissepiments, vesicular and subhorizontal, incorporated into septal structure at axis. Microstructure absent.

Discussion. – Identification of these specimens is tentative because of the poor quality of available material. The specimens are calcitic and highly recrystallized, and show little interpretive detail. The thickness of the two first orders of septa, low number of septa, and corallite diameter are indicative of *R. robusta.* Due to the poor nature of preservation, only limited gross morphology is available for identification.

Occurrence. – Norian?-Rhaetian, Lime Peak, southern Yukon, Canada; Northern Calcareous Alps.

Family REIMANIPHYLLIIDAE Melnikova, 1975

Subfamily DISTICHOFLABELLINAE Roniewicz, 1989

Genus DISTICHOFLABELUM Roniewicz, 1989

Type Species. – Distichoflabellum zapfei Roniewicz, 1989

DISTICHOFLABELLUM sp.

(Plate 1, Figures 4, 5)

Margarophyllia sp. ZANKL, 1969, p. 37, text-fig. 36, Pl. 2, fig. 14.

Distichoflabellum zapfei RONIEWICZ, 1989, p. 74, Pl. 6, fig. 5.

Material. – Two hand samples and thin sections of corals in a limestone matrix; Reid Collection: Fig. A 14a, from Lime Peak (61º03.5’N, 134º54’W) and CC-298, from the Cap Creek locality (60º51’19”N, 134º41’45”W), southern Yukon, Stikine terrane.

Description. – Calices poorly distinguished, probably not individual, flabellate in shape, forming a conical shape with a platy corallum. Corallite diameter 15 – 25 mm. At least two septal orders, fusiform; S1 are thickest, club shaped, bend at axial fissure; S2 are thinner, sporadic. Septa show straight to wavy, thin median line; thin dissepiments and abundant granules present.

Discussion. – The specific identification of this species is tentative due to the lack of comprehensive and abundant material for study. However, observations of general morphology concur with descriptions of the genus *Distichoflabellum* and, in particular, the species *D. zapfei* Roniewicz. Little is known about this species as it is known only from Europe. Additional collection of material and further study of current specimens are needed to make a proper identification.

Occurrence. – Norian?- Rhaetian, Lime Peak, southern Yukon, Canada; Northern Calcareous Alps and Zlambach Beds, Austria.

Family MARGAROPHYLLIIDAE Cuif, 1977

Genus DISTICHOMEANDRA Cuif, 1976

Type Species. – Isastraea austriaca Frech, 1890

DISTICHOMEANDRA AUSTRIACA (Frech, 1890)

(Plate 3, Figure 1)

Isastraea austriaca FRECH, 1890, p. 23, Pl. 6, figs. 1-3, 5, 6, [not Pl. 6, fig. 4].

Isastraea eucystis FRECH, 1890, p. 26, Pl. 6, figs. 10, 10A, [not Pl. 7, figs. 11, 11A, 12, 12A].

"Isastraea" eucystis (Frech). MATZNER, 1986, Pl. 9, fig. 7.

Margarastraea eucystis (Frech). STANLEY, 1979, p. 56, Pl. 1, fig. 2.

Distichomeandra austriaca (Frech). RONIEWICZ, 1989, p. 79, Pl. 20, figs. 1, 6, Pl. 21, figs. 5, 6, Pl. 22, fig. 1; STANLEY, In Stanley et al., 1994, p. 12, figs. 9.1, 9.2, 9.10, 9.11;

Distichomeandra cf. *austriaca* (Frech). STANLEY AND SENOWBARI-DARYAN, 1999, p. 794, figs. 5.7 – 5.10.

Material. – One massive colony, UMIP 2.20079, from the Lime Peak reef complex, southern Yukon, Stikine terrane (61º03.5'N, 134º54'W).

Description. – Colony compact and cerioid, corallites oval to lobate, but tend to elongate, giving the coral a meandroid appearance. Colony 7.5 cm in length, 2.5 cm thick; widths between colline ridges: 3.0 – 6.0 mm. Corallite diameters average 6.0 x 7.0 mm; with 7 – 8 septa per 3.0 mm. At least three septal orders present, a fourth order may be masked by weathering. S1 septa strong and thicken as reach center; septal faces granular. Calices deep with high ridges and steep walls. Microstructure absent.

Discussion. – Although this specimen is internally poorly preserved and externally weathered, there is enough surface detail to verify the identification. The size of corallites, characteristics of septa, and general coral morphology correspond closely to the descriptions of Roniewicz (1989) and Stanley et al. (1994). The presence of both cerioid and elongated (pseudo meandroid) corallites is a typical feature of *D. austriaca.*

Occurrence. – Norian-Rhaetian, Lime Peak, southern Yukon, Canada; Pilot Mountains, Nevada; Sonora, Mexico; Zlambach beds and Northern Calcareous Alps, Austria.

Suborder FUNGIINA Verrill, 1865, *faute de mieux*

Superfamily PROCYCLOLITOIDEA Vaughan and Wells, 1943

Family PROCYCLOLITIDEA Vaughan and Wells, 1943

Subfamily PROCYCLOLITINAE Vaughan and Wells, 1943

Genus PROCYCLOLITES Frech, 1890

Type Species. – Procyclolites triadicus Frech, 1890

PROCYCLOLITES TRIADICUS Frech, 1890

(Plate 3, Figure 2)

Procyclolites triadicus FRECH, 1890, p. 64, Pl. 18, figs. 1-16, text-fig. on p. 65; ZANKL, 1969 (as *Procyclolithes)*, p. 31, text-fig. 22, Pl. 2, fig. 9; MATZNER, 1986, Pl. 10, fig. 7; RONIEWICZ, 1989, p. 85, Pl. 23, figs. 1-3, Pl. 24, figs. 1, 2.

Procyclolites clipeiformis HAAS, 1909, p. 153, Pl. 5, fig. 14.

Procyclolites depressus HAAS, 1909, p. 153, Pl. 5, fig. 15.

Procyclolites sp. cf. *P. triadicus* Frech. KANMERA, 1964, p. 129, Pl. 12, fig. 11-15.

Genus *Procyclolites* Frech. CUIF, 1975b, p. 85, text-fig. 11, Pl. 9, figs. 1, 2, Pl. 10, figs. 1-8.

Material. – Four specimens in a silty limestone matrix, two are cut and polished. Reid Collection: R-80-5-10A, R-80-7A-1, R-81-3, and R-81-21-4. All from Lime Peak reef complex, southern Yukon, Stikine terrane (61º03.5'N, 134º54'W).

Description. – Corallites discoid to trochoid in shape, average diameter about 80 x 50mm. Calices lobate to elliptical. Numerous (200 – 250) thin septa, closely spaced; S1 septa reach axial fissure and intertwine, forming parietal columella. Three orders of septa, regularly distributed: S2 septa long, but shorter than S1, S3 septa up to half the length of S1. Abundant endotheca with small dissepiments. R-81-3 and R-81-21-4 show rejuvenescence or budding. Microstructure absent.

Discussion. – Since microstructure is not preserved in the specimens, the detailed descriptions and observations by Cuif (1975 b) are not applicable. However, the gross morphology agrees well with descriptions and figures of Roniewicz (1989) and Zankl (1969).

Occurrence. – Norian, Lime Peak, southern Yukon, Canada; Zlambach beds, Austria; Hohe Göll limestone, Alps; Japan.

Family ASTRAEOMORPHIDAE Frech, 1890

Genus ASTRAEOMORPHA Reuss, 1854

Type Species. – Astraeomorpha crassisepta Reuss, 1854.

ASTRAEOMORPHA SONORENSIS Stanley, 1994

(Plate 5, Figures 1, 2)

Astraeomorpha confusa (Winkler). STANLEY, 1979, Pl.1, fig. 11, 3.

Astraeomorpha sonorensis STANLEY, In Stanley et al., 1994, p. 14, figs. 12.3-12.6.

Material. – Two massive colonies, 3.0 – 5.0 cm thick, polished and thin sectioned. UMIP 2.20085 and 2.20086. From Lime Peak reef complex, southern Yukon, Stikine terrane, (61º03.5'N, 134º54'W).

Description. – Colonies massive and exhibit vertical laminar growth pattern. Wavy, thamnasteroid septa, 10 – 14 in number, with distinct bilaminar plates. Distance between corallite centers: 1.0 – 2.1 mm. Small styliform columella and abundant axiferous menianes (3 – 4 per 1 mm) form wavy horizontal plates. Thin dissepiments present.

Discussion. – Stanley *et al.* (1994) first described this species from the Antimonio Formation, Sonora, Mexico. These specimens agree with the type material from Sonora. The meniane spacing and distance between corallite centers set *A. sonorensis* apart from *A. crassisepta* Reuss and *A. confusa* (Winkler).

Occurrence. – Norian, Lime Peak, southern Yukon, Canada; Sonora, Mexico; Pilot Mountains, Nevada.

Suborder ARCHAEOCOENIINA Alloiteau, 1952

Family ACTINASTRAEIDAE Alloiteau, 1952

Genus CHONDROCOENIA Roniewicz, 1989

Type Species. – Prionastraea schafhaeutli Winkler, 1861

CHONDROCOENIA SCHAFHAEUTLI (Winkler, 1861)

(Plate 4, Figures 1, 2)

Prionastraea ? Schafhäutli WINKLER, 1861, p. 488, Pl. 8, fig. 11.

Isastraea Süssi REUSS, 1865, p. 162, Pl. 2, fig. 4.

Stephanocoenia Schafhäutli Winkler. FRECH, 1890, p. 37, text-fig. on p. 36 (A, B) and two text-figs. on p. 37.

Stephanocoenia juvavica FRECH, 1890, p. 38, right text-fig. on p. 38.

Cyathocoenia schafhaeutli (Winkler). MELNIKOVA, 1968, p. 14, Pl. 3, figs. 3, 4; 1975, p. 59, text-fig. 8, Pl. 2, figs. 4, 5, Pl. 4, figs. 1, 2; FANTINI-SESTINI AND MOTTA, 1984, p. 350, Pl. 28, fig. 3, Pl. 29, fig. 2.

Cyathocoenia alpina Gümbel. RONIEWICZ, 1974, p. 103, text-figs. 3 a, b, Pl. 1, figs. 3, 4.

Stephanocoenia schafhaeutli Frech. SENOWBARI-DARYAN, 1980, p. 41, Pl. 5, fig. 1.

Astrocoenia schafhaeutli (Winkler). SQUIRES, 1956 (as *A. schafhäutli*), p. 9, figs. 1-3; KRISTAN-TOLLMANN, TOLLMANN, AND HAMEDANI, 1980, p. 169, Pl. 1, figs. 1-4.

Actinastraea juvavica (Frech). WURM, 1982, p. 218, Pl. 34, fig. 6.

"Actinastraea". REID, 1985, p. 285, fig. A16.

Cyathocoenia squiresi STANLEY, 1986, p. 28, Pl. 3.1, fig. 10; PRINZ, 1991, p. 158, Pl. 1, fig. 8; PRINZ-GRIMM, 1995, p. 239, fig. 7, fig. 8i.

Chondrocoenia schafhaeutli (Winkler). RONIEWICZ, 1989, p. 104, Pl. 33, figs. 1-3, 5.

Material. – Two specimens, in a limestone matrix, Reid Collection: Fig. A16, and R-80-18-2A. In specimen Fig. A16, *C. schafhaeutli* is present in both growth forms. From Lime Peak reef complex, southern Yukon, Stikine terrane, (61º03.5'N, 134º54'W).

Description. – Both lamellate and hemispherical colonies, diameter of hemispherical colony 30 mm. Calices polygonal, shallow, with small, styliform columella. Calice diameters average 2.5 mm and distance between corallite centers is 2.5 – 3.0 mm. Septa thin, abundantly granulated; two orders, numbering 20 – 24. Wall between opposing calices wavy. Columella, although mostly poorly preserved, appear with traces of paliform projections. Specimen R-80-18-2A shows layered growth habit, coral interlayered with limestone-coquina matrix.

Discussion. – This coral is known to exhibit great variability in growth form and corallite size. These specimens fit well descriptions made by Melnikova (1968).

It is well illustrated by Frech (1890) and Roniewicz (1989), and also by Squires (1956). Stanley (1986) stated that Squires' species is not similar to Winkler's (1861) type, based on remarks made by Montanaro Gallitelli *et al.* (1979). This is not the case, however, as these remarks are in reference to comparison with the species *Cyathocoenia* aff. *carinata*, not Winkler's description of *C. schafhaeutli.* Therefore, Squires' (1956) identification still stands and Stanley's (1986), Prinz's (1991), and Prinz-Grimm's (1995) *Cyathocoenia squiresi* should be reexamined for validity.

Occurrence. - Rhaetian, Lime Peak, southern Yukon, Canada; Vancouver Island (Lake Cowichan); Lewiston, Idaho; Chile; Zlambach beds, Austria; southern Alps, Italy; southeastern Pamir Mountains, U.S.S.R.

CHONDROCOENIA WALTHERI (Frech, 1890)

(Plate 4, Figures 3, 4)

Astrocoenia waltheri FRECH, 1890, p. 34, fig. on p. 34; SCHÄFER, 1979, p. 48, Pl. 11, fig. 5.

Actinastraea waltheri (Frech). STANLEY, 1979, p. 13, Pl. 1, fig. 6.

Chondrocoenia waltheri (Frech). RONIEWICZ, 1989, p. 106, Pl. 33, fig. 6; STANLEY, In Stanley et al., 1994, p. 14, figs. 9.3-9.5, 11.1-11.3; STANLEY AND SENOWBARI-DARYAN, 1999, p. 797, figs. 6.6-6.9.

Material. – Five massive hemispherical colonies, one lamellate colony. All weathered out from limestone; cut and polished, one thin section. UMIP 2.20061, 2.20073, 2.20090, and 2.20102; Reid Collection: R-80-3-19F and R-81-

25-10. One colony in limestone matrix, LP-C-498. From Lime Peak reef complex, southern Yukon, Stikine terrane, (61º03.5'N, 134º54'W).

Description. – Colonies hemispherical in shape, average 40 mm in diameter. Calices polygonal to round, fairly shallow, and range from 2.0 – 2.5 mm in diameter. Distance between corallite centers ranges from 2.0 – 3.5 mm. Septa thick and occur in at least two orders: S1 septa reach center where they reach a styliform columella, providing reinforcement, and S2 septa shorter. Septa laterally granular and average 24 in number. Endotheca contains thin dissepiments.

Discussion. – The specimens correspond with the descriptions of Roniewicz (1989, p. 106) and Stanley *et al.* (1994, p. 16) in that they display "pentameral disposition of septal triads" in calical symmetry. The specimens are also comparable to illustrations by Frech (1890) of the original type material.

Occurrence. – Norian, Lime Peak, southern Yukon, Canada; Sonora, Mexico; Zlambach beds, Austria; Pilot Mountains, Nevada.

Suborder ASTRAEOINA Alloiteau, 1952

Family PAMIROSERIIDAE Melnikova, 1984

Genus CRASSISTELLA Roniewicz, 1989

Type Species. – Stephanocoenia juvavica Frech, 1890

CRASSISTELLA JUVAVICA (Frech, 1890)

(Plate 5, Figures 3 – 5)

Astrocoenia nov. sp. FRECH, 1890, p. 36, text-fig. on p. 36.

Stephanocoenia juvavica FRECH, 1890, p. 38, text-fig. on p. 38.

Tropoiastraea schindyensis MELNIKOVA, 1975, p. 67, Pl. 5, figs. 1, 2, Pl. 6, figs. 1, 2.

Actinastraea juvavica (Frech). SENOWBARI-DARYAN, 1980, p. 42, Pl. 5, fig. 3; WURM, 1982, p. 218, Pl. 34, fig. 6.

Toechastraea plana vesiculosa MELNIKOVA (*in* Dronov, *et al.*), 1982, p. 118, Pl. 16, figs. 3-5.

? Rhaetiastraea vesiculosa MELNIKOVA – Melnikova and Bychkov, 1986, p. 76, Pl. 8, fig. 2, text-figs. 11, 12.

Crassistella juvavica RONIEWICZ, 1989, p. 113, Pl. 34, figs. 1, 2, Pl. 35, figs. 1, 2.

Crassistella cf. *C. juvavica* (Frech). STANLEY, 1994b, p. 86, Pl. 4, fig. 1; STANLEY AND SENOWBARI-DARYAN, 1999, p. 797, figs. 6.2-6.3.

Material. – One massive colony partially weathered out from a limestone matrix, two thin sections; one small colony fragment; Reid Collection: R-80-18-9, R-80-8A-3. From the Lime Peak reef complex, southern Yukon, Stikine terrane, (61º03.5’N, 134º54’W).

Description. – Colony lamellate, formed by tabular overgrowth of new generations of corallites over older generations. Cerioid, with flat wall dividing deep calices. Corallite diameters range from 1.9 – 2.5 mm and septa average 28 in number. Septa wedge-shaped and occur in 2 – 3 size orders. S1 and mostly S2 reach styliform columella, S3 septa shorter than half the length of S1 septa. Dividing wall between corallites composed of opposing, confluent biseptal blades, disposed alternately in wall so that well developed S1 or S2 septa of one corallite reach directly into S3 septa of a neighboring corallite. Septal faces highly granular and endotheca composed of thin-walled vesicles. Microstructure absent.

Discussion. – This specimen matches well with the species described by Frech (1890) and Roniewicz (1989). The confluent biseptal elements are a distinctive feature of the species and a characteristic readily observed in thin section of the specimen.

Occurrence. – Norian-Rhaetian, Lime Peak, southern Yukon, Canada; Eaglenest reef, Quesnel terrane, Canada; Northern Calcareous Alps and Zlambach beds, Austria; Pamir Mountains, U.S.S.R.; and northeast Asia.

Phylum MOLLUSCA

Class BIVALVIA Linné, 1758

Order HIPPURITOIDA Newell, 1965

Superfamily MEGALODONTOIDEA Morris and Lycett, 1853

Family WALLOWACONCHIDAE Yancey and Stanley, 1999

Genus WALLOWACONCHA Yancey and Stanley, 1999

Type Species. – *Wallowaconcha raylenea* Yancey and Stanley, 1999

Wallowaconchid bivalves belong to a newly named family first discovered and described from the Black Marble Quarry located on the eastern margin of the northern Wallowa Mountains in Oregon (Yancey and Stanley, 1999). The bivalves are physically unique and are easily identified by their large size and protruding chambered wing structures. Only two forms of wallowaconchid are known, the type species from the Wallowa terrane in Oregon, and another, smaller taxon which Yancey and Stanley (1999) were only able to identify as *Wallowaconcha* sp. due to insufficient details of the material. This smaller form occurs in the Antimonio terrane in Sonora, Mexico and the Chulitna terrane in Alaska. The wallowaconchids from Canyon Mountain, Yukon, appear similar to those found in Oregon, however, poor preservation and limited exposure of continuous rock outcrop allow only tentative identification. A thorough reconnaissance of the locality in the future may yield more suitable information.

WALLOWACONCHA cf. W. RAYLENEA Yancey and Stanley, 1999

(Plate 8, Figures 1, 2)

Dicerocardium REID, 1985, p. 42, text-fig. 17b, p. 318, text-fig. A28b.

“Alatoform bivalve” In STANLEY et al., 1994, p. 4, text-fig. 6.

Wallowaconchid YARNELL, STANLEY, AND HART, 1998, p. 182, text-fig. 6, 7.

Wallowaconcha reylenea YANCEY AND STANLEY, 1999, p. 10, text-figs. 2 – 6, Pl. 1 – 3.

Material. – One large body cavity with “wing”; various shell, body, and “wing” fragments; one hinge fragment; and one half of a whole specimen – weathered out from limestone. From Canyon Mountain (also known as Gray Mountain), Whitehorse area, Yukon, (60º39'25"N, 134º53'20"W). Also figured but not sampled from Emerald Lake (also known as Spirit Lake, 60º15'44"N, 134º45'28"W), southern Yukon, Stikine terrane.

Description. – Measurements of wing length both in field and laboratory show lengths from 20 to 30 cm.   Wings 20 mm apart, with partitions spaced 20 – 25 mm apart. Shell wall up to 5.0 mm thick.

Discussion. – Although few whole specimens were collected and prepared as to properly examine the hinge structure, field observations and measurements argue for a conspecific relationship with *W. raylenea.* Yancey and Stanley (p. 14, Pl. 4, fig. 6, 1999) report this species from Mount McIntyre in Yukon, however, this information is incorrect. It should be noted that the actual locality, first reported by Reid (described as *Dicerocardium*, p. 318, text-fig. A28b, 1985), is at Emerald Lake, south-southeast of Whitehorse, Yukon. I confirm the occurrence of *W. raylenea* at this locality, but I was unable to collect samples due to the nature of the limestone outcrop. Reid (p. 42, text-fig. 17b, 1985) also figured a specimen of *W. raylenea* from Lime Peak.

Occurrence. – Norian, Canyon Mountain, Emerald Lake, and Lime Peak, southern Yukon, Canada; Black Marble Quarry, Wallowa Mountains, Oregon.

LONG CREEK, ALASKA

Class ANTHOZOA

Order SCLERACTINIA Bourne, 1900

Suborder CARYOPHYLLIINA Vaughan and Wells, 1943

Superfamily REIMANIPHYLLIOIDEA Melnikova, 1975

Family DISTICHOPHYLLIIDAE Cuif, 1977

Genus DISTICHOPHYLLIA Cuif, 1975a

Type Species. – Montlivaltia norica Frech, 1890

DISTICHOPHYLLIA cf. D. NORICA (Frech, 1890)

(Plate 6, Figures 1, 2)

Montlivaltia cupuliformis REUSS, 1854, p. 102, Pl. 6, figs. 16, 17.

Montlivaltia norica FRECH, 1890, p. 39, Pl. 3, figs. 8, 9, Pl. 10, figs. 1-5, Pl. 18, fig. 17.

Montlivaltia gosaviensis FRECH, 1890, p. 41, Pl. 11, fig. 7.

Montlivaltia norica Frech. VINASSA DE REGNY, 1915, Pl. 71, figs. 15-17; SMITH, 1927 (as *Montlivaultia*), p. 126, Pl. 111, fig. 6; SQUIRES, 1956, p. 21, figs. 32-47; CUIF, 1966, p. 535, Pl. 11, figs. 3-5; WU, 1975, Pl. 4, figs. 6, 7; SCHÄFER, 1979, p. 44, Pl. 10, fig. 1, Pl. 11, fig. 2; STANLEY, 1979, Pl. 2, figs. 8-10; KRISTAN-TOLLMANN, TOLLMANN, AND HAMEDANI, 1980, Pl. 6, figs. 1-4.

Montlivaltia sp. cf. *M. norica* Frech. KANMERA, 1964, p. 120, Pl. 12, figs. 6-10.

“Montlivaltia” reussi Milne-Edwards and Haime. ZANKL, 1969, p. 31, text-fig. 20, Pl. 2, fig. 10.

Montlivaltia norica, Distichophyllia (Montlivaltia) norica (Frech). CUIF, 1975a, p. 304, text-figs. 2-6.

Reimaniphyllia gosaviensis (Frech). MELNIKOVA, 1975, (part), p. 87, Pl. 15, fig. 1 (not fig. 2).

Distichophyllia norica (Frech). CUIF, 1977, Pl. 4, figs. 5-7; STANLEY, 1986, Pl. 3.1, figs. 4-6; STANLEY AND WHALEN, 1989, p. 806, figs. 5.4, 5.6; RONIEWICZ, 1989, p. 39, Pl. 6, figs. 2-4; STANLEY, 1994b, p. 88, Pl. 4, figs. 3, 4.

Distichophyllia cf. *norica* (Frech). MONTANARO-GALLITELLI, RUSSO, AND FERRARI, 1979, p. 149, Pl. 4, fig. 9a, b; MELNIKOVA AND BYCHKOV, 1986, Pl. 6, fig. 2.

Material. – Two weathered out, solitary corals: UMIP 2.24711, 2.24714; two in a single limestone matrix: UMIP 2.24651, 2.24656; and two thin sections: UMIP 2.24654, 2.24667. From Long Creek, west of Golden Zone Mine, Chulitna terrane, Alaska (63º12'N, 149º42'W).Description. – Colonies solitary, but with pseudocolonial lateral buds; trochoid in shape; corallite diameter 20 – 35 mm. Septa numerous, up to 70 in at least four orders; S1, S2 septa club-shaped and characterized by a zig-zag median. Dissepiments thin, abundant; granules present; columella seems pallilar.

Discussion. – Identification of the specimens is tentative because they are, in general, poorly preserved. The specimens are recrystallized and contain minor amounts of pyritization. *Distichophyllia norica* is an extremely widespread species, but in the Chulitna specimens, contrary to their European Alpine counterparts, budding is common and they appear pseudocolonial. Zankl (1969) illustrated a budding coral from the Hohe Göll that he called *Montlivaultia reussi*, however, this may instead be the pseudocolonial form of *Distichophyllia norica.* Stanley (1986), Stanley and Senowbari-Daryan (1986), and Stanley and Whalen (1989) also noted the pseudocolonial habit in *D. norica* from Hells Canyon, Oregon and the Wallowa terrane.

Occurrence. – Norian-Rhaetian, Long Creek, Alaska; Hells Canyon, Oregon; Lewiston (Mission Creek), Idaho; Pilot Mountains, Nevada; Vancouver Island (Lake Cowichen), Canada; Wrangell Mountains, Alaska; Dachstein Reef Limestone and Zlambach beds, Austria; Mt. Everest, Tibet; Timor; southeastern Pamir Mountains and Koryak Highlands, northeast U.S.S.R.; Peru; Japan.

DISTICHOPHYLLIA MARMOREA (Frech, 1890)

(Plate 6, Figure 3)

Montlivaltia marmorea FRECH, 1890, p. 41, Pl. 11, figs. 6, 6A; SMITH, 1927, (as *Montlivaultia*), p. 126; ZANKL, 1969, (as “*Montlivaltia*”), p. 31, text-fig. 21, Pl. 2, fig. 12.

Material. – Two solitary corallites, UMIP 2.24661 and 2.24662; one half of a corallite in a limestone matrix, UMIP 2.24652, transverse and longitudinal cut thin sections. Sampled along stream cut of Long Creek, west of Golden Zone Mine, Chulitna terrane, Alaska (63º12’N, 149º42’W).

Description. – Large solitary coral, similar to *D. norica*, but differentiated by its larger size and abundant septa. Calice 70 – 60 mm in diameter, cylindrical.

Columella absent and instead S1 septa thicken and meet at line in center. Four orders of septa, about 250 – 300. Numerous dissepiments present, septal faces granular.

Discussion. – This species is neither well represented in the literature nor well known from North America. Frech (1890) described the type from the Austrian Zlambach beds, and distinguished it from *D. norica* based on it larger corallite size and more numerous septa. The specimens correspond with this description. Zankl (1969) reports this species from the Hohe Göll in the Austrian Alps, and illustrates this species in a budding form. This is contradictory to the genotype classification as solitary and implies the species is pseudo-colonial. This is a morphological aspect under consideration for other North American occurrences of the *Distichophyllia* genus. Smith (1927) also reports this species in the Pilot Mountains, Nevada, but provides no specimen number or illustration and Stanley (pers. comm.) reports it from the Martin Bridge formation at Summit Point, Oregon.

Occurrence. – Norian-Rhaetian, Long Creek, Alaska; Pilot Mountains, Nevada; Summit Point, Wallowa Mountains, Oregon; Zlambach beds, Austria; Hohe Göll limestone, northern Austrian Alps.

Genus RETIOPHYLLIA Cuif, 1967

Type Species. – Thecosmilia fenestrata Reuss, 1854 *in* Frech, 1890, p. 9.

RETIOPHYLLIA cf. R. NORICA (Frech, 1890)

(Plate 6, Figure 4)

Thecosmilia norica FRECH, 1890, p. 9, Pl. 1, figs. 14-24.

Thecosmilia norica var. *densisepta* HAAS, 1909, p. 145, Pl. 5, fig. 3.

Thecosmilia norica var. *lobatisepta* HAAS, 1909, p. 145, Pl. 5, fig. 4.

Paradistichophyllum noricum (Frech). MELNIKOVA, 1975, p.90, Pl. 15, figs. 3, 4.

"Thecosmilia" cf. *"T." fenestrata* (Reuss). STANLEY, 1979, p. 56, Pl. 3, fig. 1.

Retiophyllia norica (Frech). RONIEWICZ, 1989, p. 52, Pl. 8, figs. 5-8, Pl. 9, fig. 2, Pl. 14, figs. 1, 2; STANLEY, In Stanley et al*.*, 1994, p. 12, figs. 10.1, 10.2.

Material.- Three specimens of single corallites and fragments from a large colony; UMIP 2.24670, 2.24672, 2.24722, and LC-SRC. From Long Creek, west of Golden Zone Mine, Chulitna terrane, Alaska, (63º12'N, 149º42'W).

Description.- Corallite diameter: 7 – 15 mm, folds on corallite surface. Pellicular wall thin, costae visible. Septa fusiform, in 3 – 4 orders: S1 septa thickest and reach center; S2 septa slightly shorter, thinner than S1; S3 septa about ½ the length of S1; S4 septa rudimentary or poorly preserved, reach ¼ the length of S1. Septa number 50 – 76. Lateral, upward spinal projections on corallite surface. Variable dissepiments, vesicular and subhorizontal, incorporated into septal structure at axis. Microstructure absent.

Discussion. – Identification of these specimens is tentative because of the poor quality of available material. The specimens are calcitic and highly recrystallized, and show little interpretive detail. The specimens are poor and identification is based mainly on corallite diameter and observations made *in situ*. The coral crop out along with a *Spongiomorpha* sp. in at least one large (2.0 m X 0.8 m) thicket that is slightly folded and compressed. Due to the poor nature of preservation, only limited gross morphology is available for identification. Descriptions by Roniewicz (1989) were used to compare these specimens.

Occurrence. – Norian-Rhaetian, Long Creek, Alaska; Sonora, Mexico; Zlambach beds, Austria; Pilot Mountains, Nevada.

Suborder FUNGIINA Verrill, 1865, *faute de mieux*

Superfamily PROCYCLOLITOIDEA Vaughan and Wells, 1943

Family PROCYCLOLITIDEA Vaughan and Wells, 1943

Subfamily ALPINOPHYLLIAE Roniewicz, 1989

Genus ALPINOPHYLLIA Roniewicz, 1989

Type Species. – *Alpinophyllia flexuosa* Roniewicz, 1989

ALPINOPHYLLIA FLEXUOSA Roniewicz, 1989

(Plate 7, Figures 1, 2)

Alpinophyllia flexuosa RONIEWICZ, 1989, p. 87, Pl. 25, figs. 1-3, Pl. 26, figs. 1, 2; STANLEY, In Stanley et al., 1994, p. 14, figs. 9.7-9.9; STANLEY AND SENOWBARI-DARYAN, 1999, p. 794, figs. 6.4-6.5.

Margarastraea norica (Frech). STANLEY, 1979, p. 56, Pl. 4, fig. 1.

Material. – One massive hemispherical colony, one thin section, UMIP 2.24647; one colony fragment, UMIP 2.24610, and other fragments, UMIP 2.26699, 2.24610 A, B, and 2.27004 A, B. From stream cut of Long Creek, west of Golden Zone Mine, Chulitna terrane, Alaska (63º12'N, 149º42'W).

Description. – Long, open monolinear and moncentric corallites: both meandroid and cerioid form. Monolinear corallites bifurcating and flexuous or serpentine, average 12.0 mm in width and reach up to 20.0 mm in length; collines tectiform. Septa straight- to curved, numbering 50 – 60 per corallite and 9 – 10 per 5.0 mm. Septa differentiated into three well- developed cycles; occasionally a fourth cycle present. S1 septa thicken adaxially and reach corallite center, sometimes intertwinning. S2 septa long, but shorter and thinner than S1. S3 septa thin, regularly distributed, and reach ½ the length of S1. Thin dissepiments present, but poorly preserved. Budding with direct linkages. Short, smooth inclined axiferous menianes, and some granular ornamentation. Microstructure absent.

Discussion. – The characteristics of these specimens match well with those described by Roniewicz (1989) and Stanley *et al.* (1994). The attributes of the septa, corallite shape, and budding help to identify this species as *A. flexuosa*.

Occurrence. – Norian-Rhaetian, Long Creek, Alaska; Pilot Mountains, Nevada; Sonora, Mexico; Zlambach Formation, Northern Limestone Alps, Austria.

Family ASTRAEOMORPHIDAE Frech, 1890

Genus ASTRAEOMORPHA Reuss, 1854

Type Species. – Astraeomorpha crassisepta Reuss, 1854.

ASTRAEOMORPHA CRASSISEPTA Reuss, 1854

(Plate 7, Figures 3, 4)

Astraeomorpha crassisepta REUSS, 1854, p. 127, Pl. 16, figs. 4-7; PRATZ, 1882, p. 102, Pl. 1, figs. 13-15; FRECH, 1890, p. 66, text-fig. on p. 70, Pl. 19, figs. 14-18; KRISTAN-TOLLMANN AND TOLLMANN, 1964, p. 559, Pl. 7, figs.

2, 7-9; KRISTAN-TOLLMANN, TOLLMANN, AND GEYSSANT, 1969, p. 15, Pl. 2, figs. 3, 4; MELNIKOVA, 1971, p. 29, Pl. 1, figs. 1, 2; 1975, p. 116, Pl. 23, figs. 1-6, Pl. 24, figs. 1-3, Pl. 25, fig. 1, Pl. 26, fig. 3; 1986, p. 56, Pl. 20, figs. 1-3, Pl. 21, fig. 2; RONIEWICZ, 1974, p. 113, Pl. 9, figs. 4, 5; CUIF, 1975, p. 117, text-fig. 19, Pl. 17, figs. 1-7; MONTANARO GALLITELLI, RUSSO, AND FERRARI, 1979, p. 142, Pl. 2, figs. 5a-6; SENOWBARI-DARYAN, 1980, p. 38, Pl. 2, fig. 3; FANTINI-SESTINI AND MOTTA, 1984, p. 351, Pl. 29, fig. 4; MATZNER, 1986, Pl. 9, fig. 1; STANLEY, 1986, Pl. 3.1, fig. 12; MELNIKOVA AND BYCHKOV, 1986, figs. 5, 6, Pl. 5, fig. 2; RONIEWICZ, 1989, p. 94, Pl. 28, figs. 3-5; STANLEY AND WHALEN, 1989, p. 811, figs. 5.2, 5.3; PRINZ, 1991, p. 155, Pl. 1, fig. 1; STANLEY, 1994b, p. 83, Pl. 2, figs. 1-4. PRINZ-GRIMM, 1995, p. 234, fig. 3 a.

Astraeomorpha Goldfussi REUSS, 1854, p. 127, Pl. 16, figs. 8, 9.

Thamnastraea borealis SMITH, 1927, (part), p. 131, Pl. 115, figs. 8, 9.

Astraeomorpha bulbosa WILKINS, 1937, p. 184, Pl. 9, figs. 3, 4.

Thamnasteria (Astraeomorpha) cuneata SQUIRES, 1956, p. 15, figs. 11-13.

Thamnasteria smithi Squires. STANLEY, 1979, (not Squires, 1956), Pl. 1, fig. 10.

Material. – Four massive hemispherical colonies, represented by both hand samples and thin sections. UMIP 2.24589, 2.24635, 2.24673, and 2.24705; from Long Creek, west of Golden Zone Mine, Chulitna terrane, Alaska, (63º12’N, 149º42’W).

Description. – Calices closely packed, in disorderly fashion; distance between corallite centers: 2.0 – 3.0 mm. Styliform columella. Septa thick and not abundant (up to 16); arranged in hexameral order. Septal faces with strong menianes, average 2 – 3 per one millimeter. Some pyritization present.

Discussion. – This species corresponds well to the description and figures in Roniewicz (1989). Although no microstructure is preserved, the specimens are distinguished from *A. confusa* (Winkler) by their meniane index and hemispherical growth form. It also differs from *A. sonorensis* Stanley in calicinal size and meniane spacing.

Occurrence. – Norian-Rhaetian, Long Creek, Alaska; Gravina Island, Alaska; Hells Canyon, Oregon; northern Peru; northern and southern Alps, Austria and Italy; Tatra Mountains, Poland; middle Afghanistan; central Iran; northern Caucasus Mountains, Pamir Mountains, and Koryak Highland, U.S.S.R.

Phylum MOLLUSCA

Class BIVALVIA Linné, 1758

Order HIPPURITOIDA Newell, 1965

Superfamily MEGALODONTOIDEA Morris and Lycett, 1853

Family WALLOWACONCHIDAE Yancey and Stanley, 1999

Genus WALLOWACONCHA Yancey and Stanley, 1999

Type Species. – *Wallowaconcha raylenea* Yancey and Stanley, 1999

WALLOWACONCHA sp.

(Plate 8, Figures 3, 4)

"Alatoform bivalve" In STANLEY et al., 1994, p. 4, text-fig. 6.

Material. – Two partial body cavities with wings. UMIP 2.26693 and LC-598; from Long Creek, west of Golden Zone Mine, Chulitna terrane, Alaska (63º12’N, 149º42’W).

Description. – Measurements of body cavity width both in field and laboratory show are 5 to 7 cm, “wing” length ranges from 10 to 8 cm. Wings about 10 mm apart where meets body cavity, with partitions spaced about 7 mm apart. Shell wall about 2 mm thick.

Discussion. – Specimens of the *Wallowaconcha* sp. at Long Creek were sparse and difficult to collect because they were in massive, thick limestone outcrops. The few specimens available are not detailed enough to make a more accurate species determination, however, measurements of body size and wing length indicate a possible conspecific relationship to *Wallowaconcha* sp. found in the Antimonio terrane in Sonora Mexico. Both localities contain characteristically smaller sized wallowaconchids which may prove to be a new species. Further sampling and study of these two sites are needed to confirm this.

Occurrence. – Norian, Long Creek, Alaska; possibly Sonora, Mexico.

Phylum uncertain

Class uncertain

Order SPONGIOMORPHIDA Alloiteau, 1952

Family SPONGIOMORPHIDAE Frech, 1890

Genus STROMATOMORPHA Frech, 1890

STROMATOMORPHA cf. S. CALIFORNICA Smith, 1927

(Plate 9, Figures 1-4)

Spongiomorpha californica SMITH, 1927, p. 134, Pl. CXVIII, fig. 4 (non Pl. CXIX, fig. 6).

Stromatomorpha cf. *californica* (Smith), LE MAITRE, 1937, p. 10, Pl. 2, figs. 3, 4.

Material. – Two hand samples and thin sections. LC-1098, LC-1098B; from Long Creek, west of Golden Zone Mine, Chulitna terrane, Alaska (63º12’N, 149º42’W).

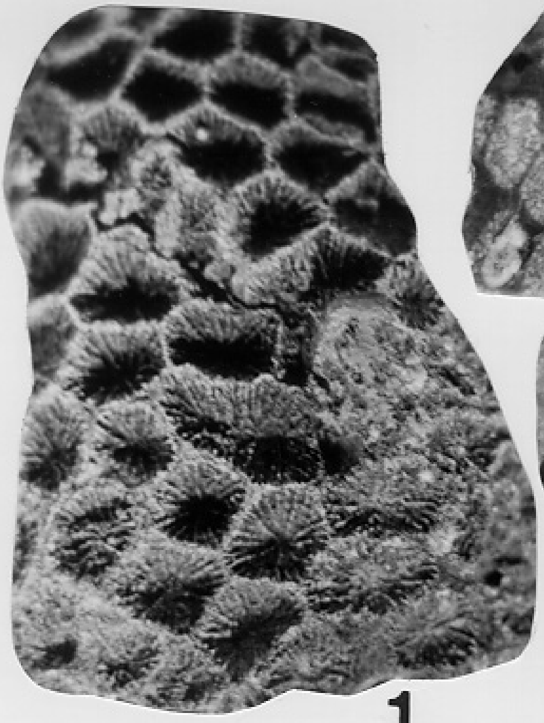
Description. – The specimens are recrystallized so their structure is poorly preserved and identification is difficult. In hand sample, horizontal layers or bands are visible and appear to differ in color only slightly which aids in their recognition. The layers are 4-5 mm in width. In thin section, the specimens appear recrystallized, but some structural components remain. A transverse cut shows small tube structures or trabeculae, about 0.7 mm in diameter. Examination of photo-micrographs also shows conspicuous spicule-like structures (Pl. 9, fig. 4).

Discussion. – Since the specimens are poorly preserved, identification is tentative. Perhaps the nature of the organism makes preservation difficult. In outcrop, the *Stromatomorpha* occur in dense colonies which form massive limestone beds. One collected sample, weathered out from the rock, appears in a conical or mushroom shape. Smith (1927) illustrates *Stromatomorpha californica* from Shasta County, California, and Gravina Island, Alaska, however, the photos are insufficient for detailed comparison. Therefore the type specimens of *Stromatomorpha californica* were examined in person, on loan from the National Museum of Natural History. Their preservation was very poor, but measurements of band thickness about 1-2 mm, and a few, sparse trabeculae were observed. The specimens at Long Creek are similar to those described by Le Maitre (1937), although they occur in the Late Triassic Norian interval whereas Le Maitre’s specimens are Early Jurassic.

Occurrence. – Norian, Long Creek, Alaska; Shasta County, California; Gravina Island, Alaska; Early Jurassic, Morocco.

PLATE 1

Lime Peak corals. *1 - 3, Gablonzeria profunda* (Reuss). *1,* view of weathered surface, UMIP 2.20070, X 2.5; *2,* polished surface, UMIP 2.20070, X 2; *3,* cut surface, slightly polished, R-81-13-5b, X 1. *4, 5, Distichoflabellum* sp. Roniewicz. *4,* polished surface, budding present although individuals likely deformed by minor strain, “Fig. A14a”, X 1.4; *5,* weathered surface, “Fig. A14a”, X 2.



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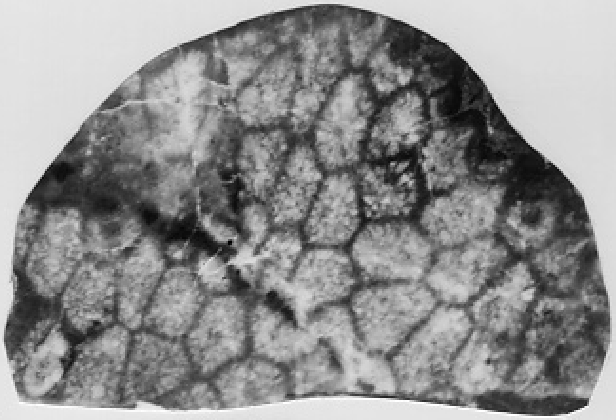

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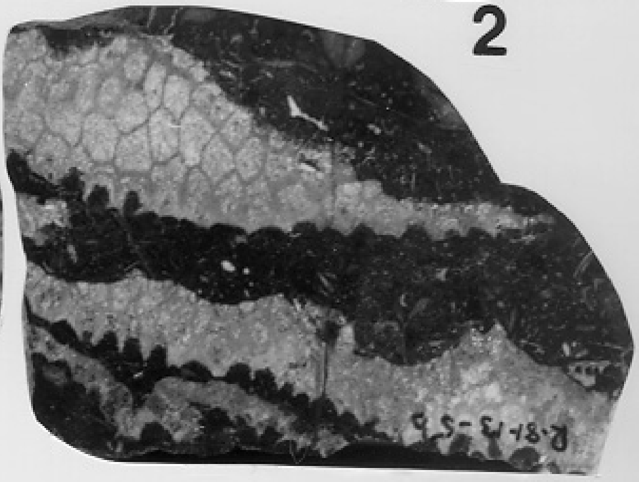

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PLATE 2

Lime Peak corals. *1, 2, Retiophyllia oppeli* (Reuss). *1,* polished surface of longitudinal cut showing thin, abundant connecting processes, TOR-79-6-1-1, X 1.6; *2,* weathered surface showing acute angle of frequent bifurcation, R-80-4-6, X 1. *3, Retiophyllia* cf. *R. robusta* Roniewicz. *3,* weathered surface, R-80-14-1A, X 2; *4, 5, Retiophyllia norica* (Frech). *4,* polished surface of longitudinal cut, “Fig. 14c” (R-LP-80), X 1; *5,* polished surface of transverse cut, “Fig. 14c” (R-LP-80), X 1.

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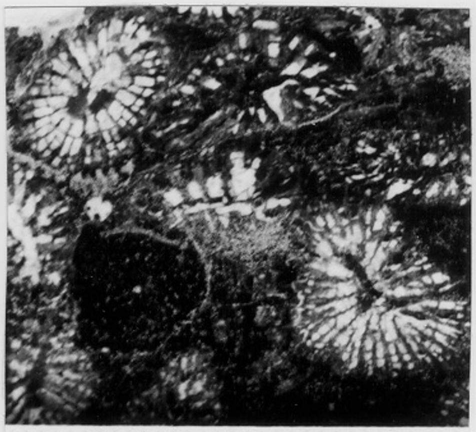

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PLATE 3

Lime Peak corals. *1, Distichomeandra austriaca* (Frech), weathered surface showing both cerioid and meandroid appearance, UMIP 2.20079, X 1.4. *2, Procyclolites triadicus* Frech, polished surface showing numerous thin septa and parietal columella, R-81-21-4, X 1.

1

2

PLATE 4

Lime Peak corals. *1, 2, Chondrocoenia schafhaeutli* (Winkler). *1,* weathered surface showing hemispherical colony shape, “Fig. A16”, X 1.8; *2,* weathered surface showing lamellate colony shape and small, styliform columella, “Fig. A16”, X 2.8. *3, 4, Chondrocoenia waltheri* (Frech). *3,* polished surface, R-80-3-19F, X 3; *4,* weathered surface showing thick septa and styliform columella, UMIP 2.20061, X 2.5.

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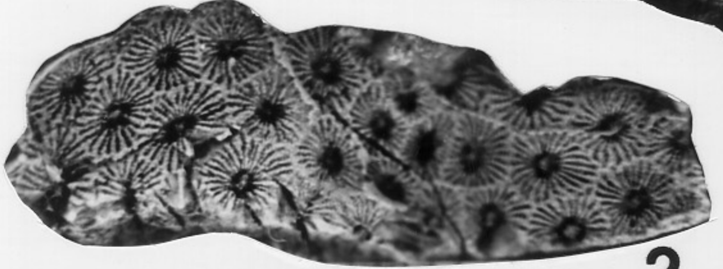

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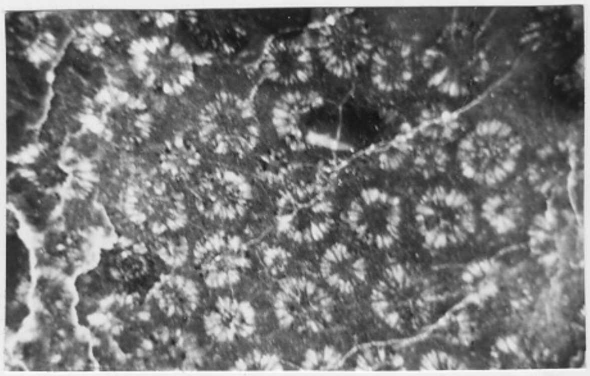

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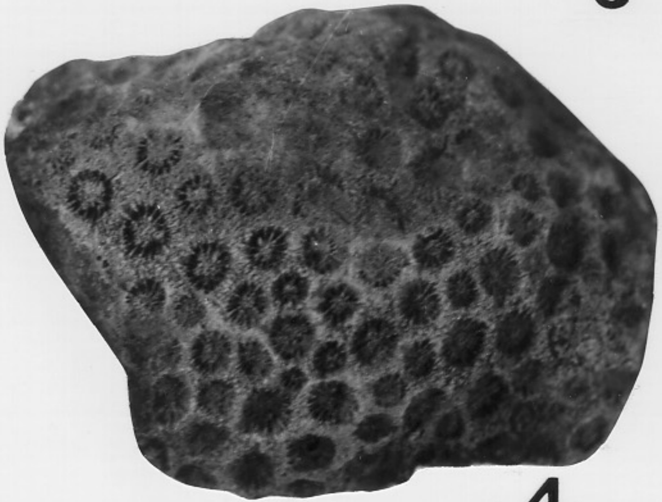

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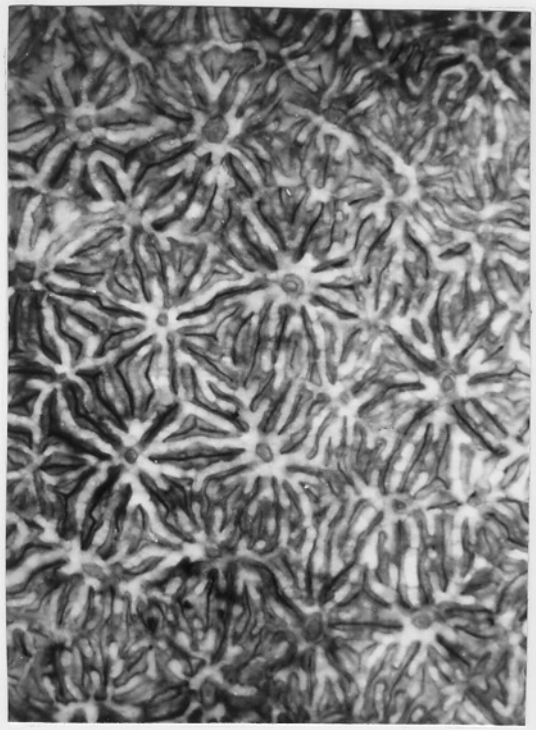
PLATE 5

Lime Peak corals. *1, 2, Astraeomorpha sonorensis* Stanley. *1,* transverse thin section showing wavy thamnasteroid septa with distinct bilaminar plates, UMIP 2.20086, X 10; *2,* longitudinal thin section showing abundant menianes, UMIP 2.20086, X 10. *3 - 5, Crassistella juvavica* (Frech). *3,* transverse thin section showing ceriod form, R-80-18-9, X 10; *4,* longitudinal thin section showing thin vesicles and abundant granules, R-80-18-9, X 20; *5,* transverse thin section showing opposing, confluent, alternately disposed biseptal blades, R-80-18-9, X 10.6.



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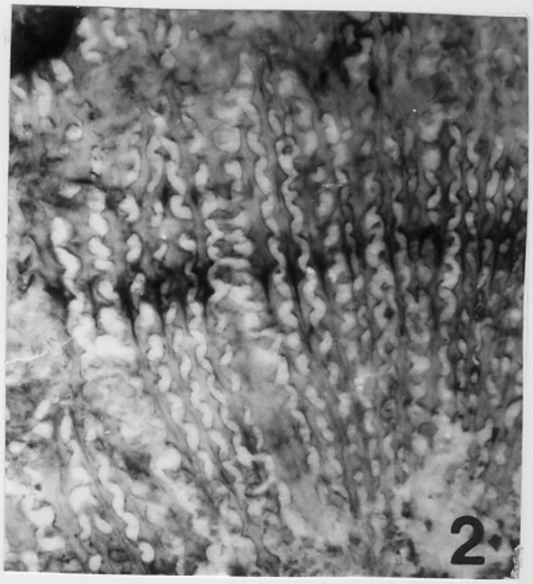

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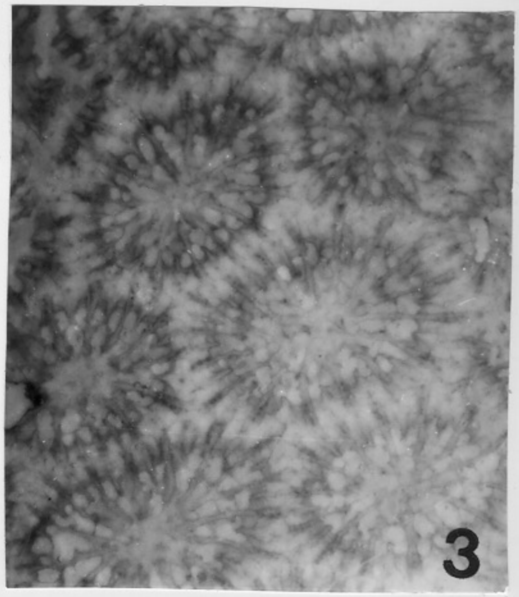

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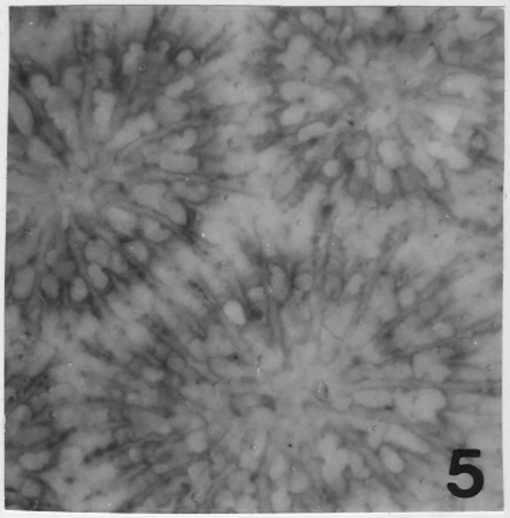

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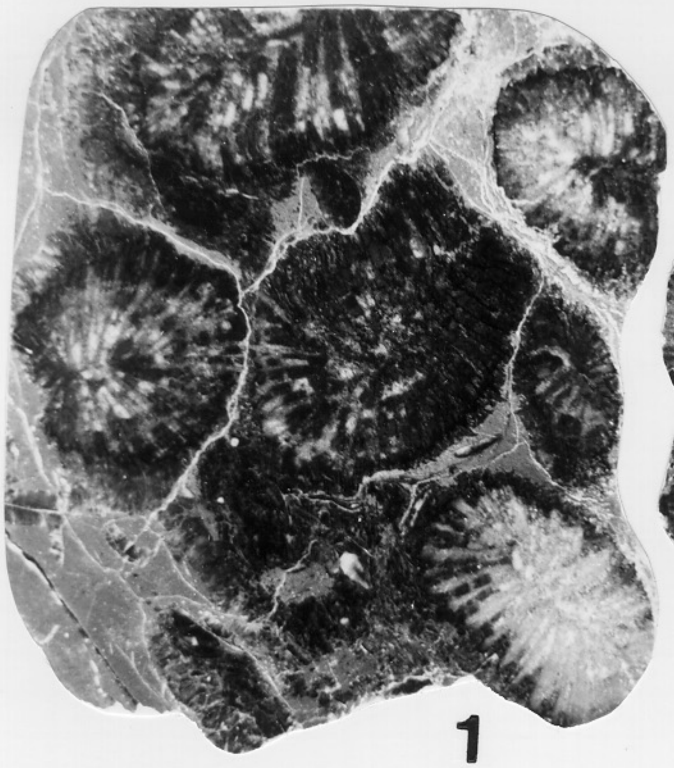
PLATE 6

Long Creek corals. *1, 2, Distichophyllia* cf. *D. norica* (Frech). *1,* polished surface, UMIP 2.24651, X 1.5; *2,* polished surface showing coral budding, UMIP 2.24656, X 1. *3, Distichophyllia marmorea* (Frech), weathered surface, UMIP 2.24662, X 1.4. *4, Retiophyllia* cf. *R. norica* (Frech), thin section of corallite, LC-298, X 10.



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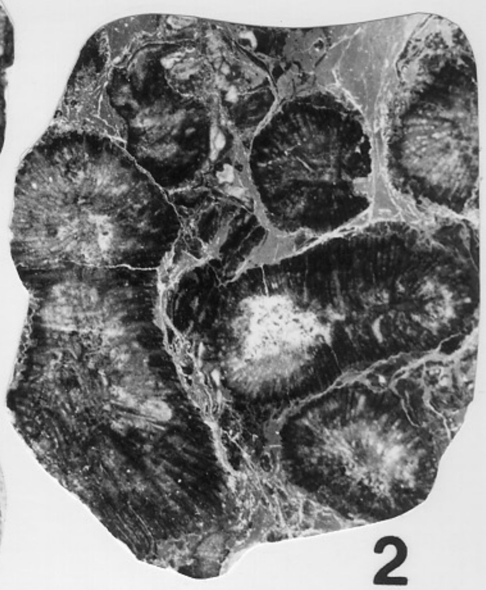

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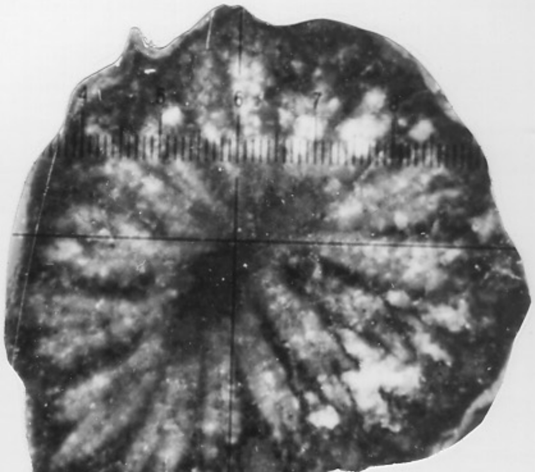

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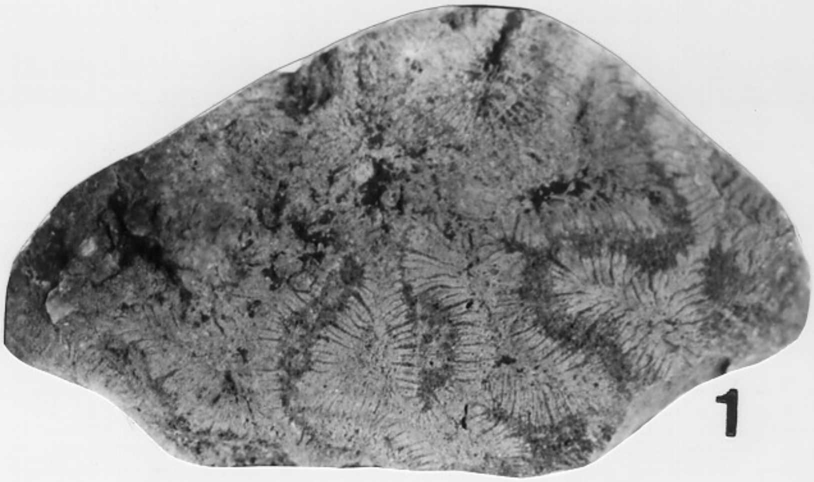
PLATE 7

Long Creek corals. *1, 2, Alpinophyllia flexuosa* Roniewicz. *1,* weathered surface, UMIP 2.24610, X 1; *2,* view of large thin section, UMIP 2.24610, X 1. *3, 4, Astraeomorpha crassisepta* Reuss. *3,* transverse thin section, UMIP 2.24673, X 10; *4,* longitudinal thin section, UMIP 2.24673, X 10.



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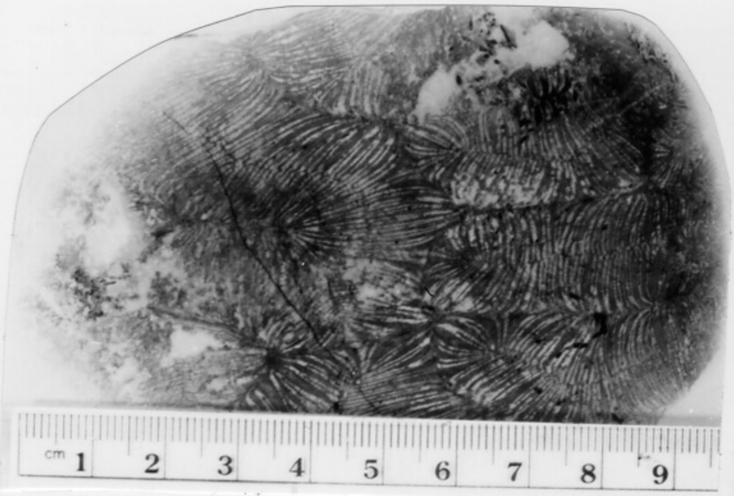

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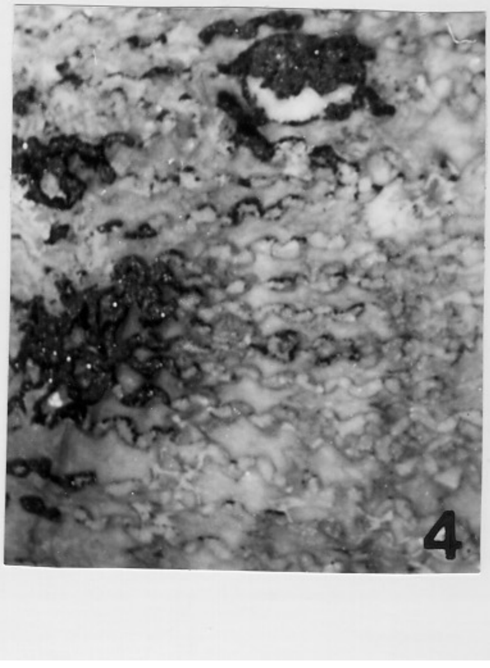

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PLATE 8

Lime Peak wallowaconchids. *1, 2, Wallowaconcha raylenea* Stanley and Yancey. *1,* view of wing and partial body cavity, UMIP 2.26693, X 0.5; *2,* view of body cavity and two partial wings, UMIP 2.26686, X 0.6.

Long Creek wallowaconchids. *3, 4, Wallowaconcha* sp. *3,* view of partial body cavity and wing, LC-598, X 1; *4,* view of partial body cavity and wing, note the wing partitions, UMIP 2.26693, X 0.8.

1

2

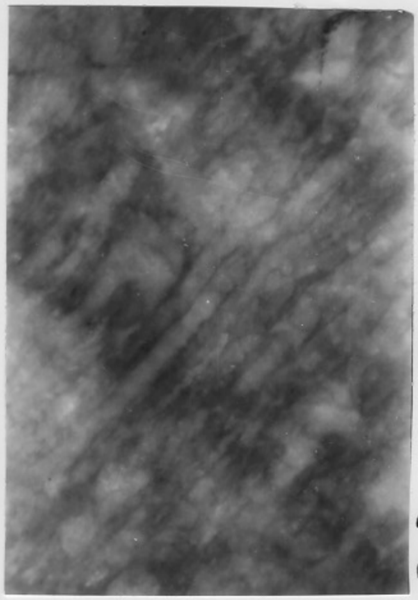
3

4

PLATE 9

1 – 4 Stromatomorpha cf. *S. californica* Smith. *1,* view of hand sample, note prominent layering, LC1098, X~ 1; *2,* tubes shown in longitudinal cut, thin section, LC1098, X 0.5; *3,* photo of thin section, LC1098, X 1; *4,* spicule-like structures shown in transverse cut, thin section, LC1098, X 10.

1



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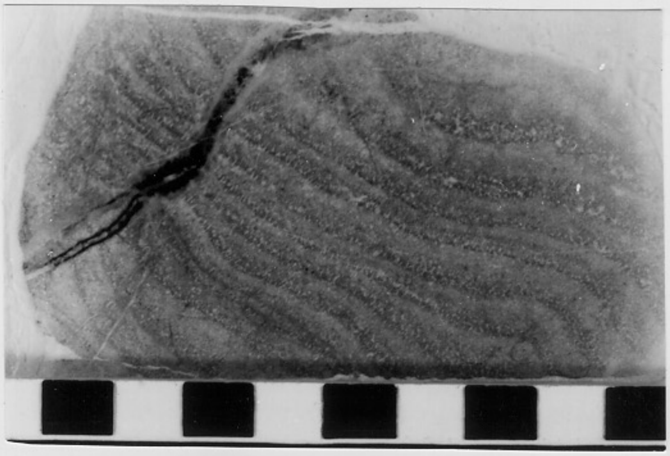

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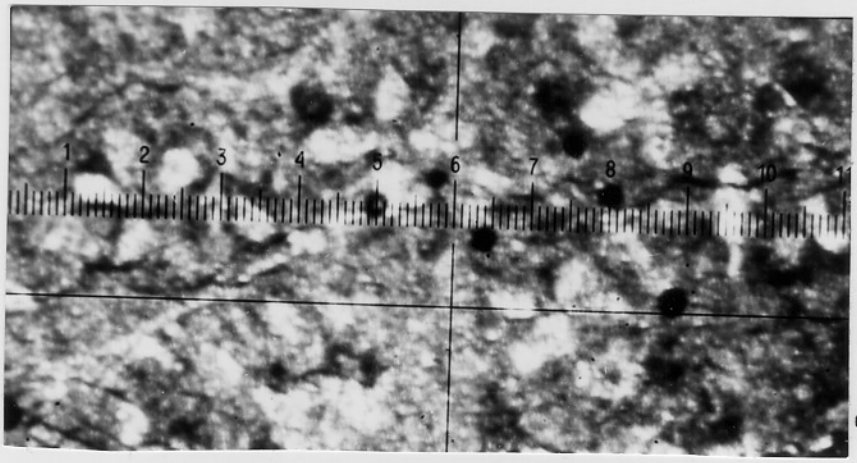

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CHAPTER V

PALEOBIOGEOGRAPHIC ANALYSIS

The science of paleobiogeography evolved from theories based on modern research in biogeography, the study of the patterns of geographical distribution of all living things. There is a long history of studies using paleobiogeography to define changes in biology, but it was the introduction of the new global tectonics theory that brought this science to a new level as a useful tool in geology. In the past, paleobiogeography played a more passive role in the field of geology and was considered useful only to distinguish distribution patterns for fossil groups of a common age. Little attention was given to the importance that paleobiogeographic analysis has in interpreting paleogeography, paleoecology, evolution, and paleoclimatology (Henderson and Heron, 1977). Early research utilizing paleobiogeography for paleogeographic interpretations are noteworthy (Stehli and Helsley, 1963; Reyment and Tait, 1972; Whittington and Hughes, 1972). However, through the years, only a few studies by paleontologists have applied paleobiogeography to terrane reconstruction by utilizing concepts of island biogeography that predict biologic interaction and sharing of fauna between geographically close terranes (Stevens and Rycerski, 1983; Stevens, 1985; Yancey and Hanger, 1986; Stevens et al., 1990; Belasky and Runnegar, 1993, 1994; Belasky, 1994; Stanley and González-León, 1995; Hanger, 1996).

Limited interest in paleobiogeographic analysis of terranes may be due to the inherently flawed nature of the fossil data. Inexact and incomplete paleontological data and additional errors in gathering information all contribute to an insufficient analysis. According to Henderson and Heron (1977), any study employing paleobiogeography must at least consider the following uncertainties:

(1) ***Incomplete records.*** "The fossil record is notoriously incomplete; it is qualified by the volume of sedimentary rock preserved for each region within the time interval of interest. . . In addition, much potential data is never established in the stratigraphic record having been destroyed by the biological and physical environment. . ." (2).

(2) ***Poor stratigraphic control on time intervals.*** "Comparing biota, or elements thereof, within particular time intervals presupposes that the time interval can be accurately recognized on a worldwide basis and that the distribution pattern was constant for the time interval concerned. . . Most contemporary investigators regard time intervals of stage and series rank as providing the best compromise" (2).

(3) ***Sampling bias among localities.*** "The selection of geographic areas for which biotic data is to be grouped is in practice arbitrary. Selection is made partially with a view to ensure that every area contains sufficient data for its affinities to be assessed. It is also qualified by the investigator's qualitative *a priori* assessment of the paleobiogeographic pattern. It is perhaps tempting to use individual rock units or even particularly rich and well known localities as the geographic units suitable for (the study), thus avoiding arbitrary groupings. . . however,

(this is) philosophically unsound because paleoecology is likely to be the major factor influencing the biotic complement of formations and localities" (2).

(4) ***Differences in nomenclature and interpretation.*** "The data potentially available for paleobiogeographical studies are defective. There are great differences in the degree to which the recoverable fossil records of different regions have been assessed. . . In addition, difficulties in comparing biotas arise from differences in the taxonomic schemes applied by the paleontologists responsible for their description. Taxonomic inhomogeneities may be simply due to the history of description; obviously biotic lists compiled last century cannot be compared directly to those resulting from modern work. However, some result from differences in taxonomic concepts between contemporary paleontologists. This is especially true for the species level, and . . . It is therefore not surprising that most workers have favored the genus as the taxon best suited to paleobiogeographic studies" (2-3).

(5) ***Cultural differences.*** Language spoken or political influence may also cause problems in paleontological studies. Information may be lost during translation from a foreign language or may be unobtainable due to political laws that forbid sharing of information freely between nations.

Despite these inherent problems of paleontology, valid paleobiogeographic analysis is still possible using statistics. Aided by computers, paleontologists use multivariate statistical methods to see through the intrinsic distortion of fossil data and reveal patterns within the complex nature of fossil data in space and time (Shi, 1993). Three statistical methods used in paleobiogeographic studies are cluster analysis, probabilistic similarity, and parsimony analysis of endemicity (PAE). All three methods are employed in this thesis to uncover paleobiogeographic relationships between the principal localities, Lime Peak and Long Creek, and other Triassic fossil coral localities within the North American Cordillera and Siberia.

Data and Methods

Data synthesized in this analysis were selected based on the guidelines summarized in Appendix A. Faunal lists comprised of Triassic fossil coral names (in the “Genus species” format) were compiled for each terrane, from fossil lists reported by Melnikova and Bychkov (1986), Schlichtholz (1997), and Goodwin (1999), and the identifications made in this thesis. The lists were then combined to form a binary data matrix in which the numbers “1” symbolize presence of a species and “0” symbolize absence (Table 2). The data matrix was thus incorporated into the following analyses: 1.) probabilistic faunal similarity index analysis (RCSI) of Raup and Crick (1979), 2.) calculation of a Jaccard similarity matrix and cluster analysis using the UPGMA algorithm of the program, MVSP (Multivariate Statistics Package) v.2.1 (Kovach, 1993), and 3.) parsimony analysis of endemicity using the phlylogenetics program, PAUP v.3.0.s

Table 2. Faunal list of the coral species used in this study. Species with an asterisk are considered endemic to the Americas.

	AL	AN	CH	EK	KR	LA	QU	ST	WA	WR
Alpinophyllia flexuosa	0	1	1	0	0	1	1	0	0	0
Ampakabastrea nodosa	0	0	0	0	0	0	0	0	0	1
Anthostylis acanthophora	0	1	0	0	0	0	0	0	1	0
Astraeomorpha confusa	1	0	0	1	1	0	0	0	1	0
Astraeomorpha crassisepta	1	0	1	0	1	0	0	0	1	0
* *Astraeomorpha sonorensis*	0	1	0	0	0	1	0	1	0	0
Beneckastraea kenkerensis	0	0	0	0	1	0	0	0	0	0
Chondrocoenia paradoxa	0	0	0	0	0	0	0	0	1	0
Chondrocoenia schafhaeutli	0	0	0	0	0	0	0	1	1	0
Chondrocoenia waltheri	0	1	0	0	0	1	1	1	0	0
Crassistella juvavica	0	0	0	1	0	1	1	1	1	0
Crassistella vesiculosa	1	0	0	1	0	0	0	0	1	0
Cuifastraea granulata	0	1	0	0	1	0	0	0	1	0
“Cyathocoenia” carinata	1	0	0	0	0	0	0	0	0	0
“Cyathocoenia” gerthi	0	0	0	0	0	0	0	0	1	0
* *“Cyathocoenia” idahoensis*	0	0	0	0	0	0	0	0	1	0
* *“Cyathocoenia” parva*	1	0	0	0	0	1	0	0	0	0
* *“Cyathocoenia” shastensis*	0	0	0	1	0	1	0	0	0	0
* *Dimorphastraea triadica*	1	0	0	0	0	0	0	0	0	0
Distichoflabellum sp.	0	0	0	0	0	0	0	1	0	0
Distichomeandra alaskana	1	0	0	0	0	0	0	0	0	0
Distichomeandra austriaca	1	1	0	1	0	1	1	1	0	0
Distichophyllia marmorea	0	0	1	0	0	1	0	0	0	0
* *Distichophyllia melnikovae*	0	0	0	0	0	0	0	0	0	1
Distichophyllia norica	0	1	1	1	1	1	0	0	1	1
Gablonzeria major	0	0	0	0	0	0	0	0	1	0
Gablonzeria profunda	1	1	0	1	0	1	0	1	1	0
* *Guembelastraea martini*	1	0	0	0	0	0	0	0	0	0
Kuhnastraea cowichanensis	1	0	0	0	1	0	0	0	1	0
Kuhnastraea descussata	1	0	0	1	0	1	0	0	1	1
Kuhnastraea incrassata	1	0	0	0	0	0	0	0	1	0
Margarastraea eucystis	0	0	0	0	0	1	0	0	0	0
* *Margarastraea pulchra*	0	0	0	0	0	0	0	0	1	0
Margarosmilia zieteni	0	0	0	0	0	0	0	0	0	1
Meandrostylis grandiseptus	0	0	0	0	0	0	0	0	1	0
Pamiroseris meriani	0	0	0	0	0	0	0	0	1	0
Pamiroseris rectilamellosa	0	1	0	1	0	1	0	0	1	0
Pinacophyllum parallelum	0	0	0	0	0	1	0	0	0	0
* *Pinacophyllum parviseptum*	0	0	0	0	0	0	0	0	1	1
Procyclolites triadicus	0	0	0	0	0	0	0	1	0	0
* *Recticostastraea wallowaensis*	0	0	0	0	0	0	0	0	1	0
Retiophyllia dawsoni	0	0	0	0	1	0	0	0	1	1
Retiophyllia delicatula	0	0	0	0	0	1	0	0	0	0
Retiophyllia frechi	1	0	0	0	0	0	0	0	1	1
Retiophyllia norica	0	1	1	0	0	1	0	1	1	0
Retiophyllia oppeli	0	1	0	0	0	0	0	1	1	1
* *Retiophyllia quesnelliana*	0	0	0	0	0	0	1	0	0	0
Retiophyllia cf. *robusta*	0	0	0	0	0	0	0	1	0	0
Rhaetiastraea? vesiculosa	0	0	0	0	1	0	0	0	0	0
Struoresia libratosepta	0	0	0	0	1	0	0	0	1	0
Stylophyllopsis lindstroemi	0	0	0	0	0	0	0	0	1	1
Stylophyllopsis rudis	0	0	0	0	0	0	0	0	1	0
Stylophyllopsis zitteli	1	0	0	0	0	0	0	0	1	0
Stylophyllum paradoxum	0	0	0	0	0	0	0	0	1	0
Thamnasteriomorpha frechi	0	0	0	0	0	0	0	0	1	1
Thamnotropis rarus	0	0	0	0	1	0	0	0	0	0
Toechastraea plana	0	0	0	0	1	0	0	0	0	0

(Swofford, 1991). Table 3 summarizes the methodology behind each statistical program. For simplification purposes, the name of the displaced terrane in which the fossil coral occur was used to symbolize “locality”. Appendix B contains information regarding the specific geographic location and geologic occurrence of Triassic fossil coral in each terrane.

Table 3: Summary of the statistical programs used for this analysis**.**

	Data Input	Analysis Type	Data Output
RCSI	Binary data matrix using “1” for presence and “0” for absence of taxa	Analysis to test the probability that the number of species in common will be less than or equal to the number of species expected to be in common on the assumption of random sprinkling of species.	Probabilistic similarity matrix – numbers closest to 1 indicate faunal similarity and numbers closest to 0 indicate dissimilarity.
MVSP	Binary data matrix using “1” for presence and “0” for absence of taxa	Calculation of a similarity matrix using the Jaccard coefficient [A/(A+B+C)] (where A = # of taxa in common, B = # of taxa in first sample, and C = # of taxa in second sample, etc.) and then subjecting it to an average linkage cluster analysis using the UPGMA algorithm of the program. With UPGMA, every individual point of a cluster is given weight, thus the weight of a cluster is proportional to the number of points it contains.	Produces a dendrogram showing similarity if two or more localities cluster together.
PAUP	Binary data matrix using “1” for presence and “0” for absence of taxa	Parsimony analysis of endemicity (PAE) – a phylogenetic analysis using the “Dollo” character to imply that in evolution, it’s harder to gain a complex feature than to lose it (called reversal). In this case, the “shared” traits are the taxa themselves. This method is unrooted, operating with no ancestor.	Phylogenetic tree showing the evolved relationship between localities – calculate a 50% majority-rule consensus tree if there is more than one tree.

Results

The analyses were performed at the species level due to the fact that, in general, the localities have been well sampled and the naming of species is fairly well accepted. Initial runs performed at the genus level revealed generally similar results and therefore analyses at the species level are considered with confidence, a more accurate approach. Figure 1 shows the location of the terranes and Table 4 gives the symbol and name for each locality.

Table 4: Localities of Triassic faunas used in this study. These symbols are also used in other tables and figures.

SYMBOL	TERRANE	FORMATION	AGE
AL	Alexander	Nehenta Fm.	Early Norian (Kerri)
AN	Antimonio	Antimonio Fm.	? late Middle-early Late Norian
CH	Chulitna	Chulitna sequence	Norian
EK	Eastern Klamath	Hosselkus Ls.	? Early Norian (Kerri)
KR	Koryak Highlands	Kenkeren ridge ls.	Norian
LA	Luning Allochthon	Luning Fm.	Early Norian (Kerri-Magnus)
QU	Quesnel	Takla Group	Early-Middle Norian
ST	Stikine	Hancock Ls.	Norian
WA	Wallowa	Martin Bridge Fm.	Early Norian (Kerri)
WR	Wrangellia (North)	Chitistone Ls.	Early Norian (Kerri)

RCSI. Table 5a and 5b show the results of running the Raup and Crick (1979) probabilistic faunal similarity index (RCSI) analysis program. Table 5b summarizes the resultant similarity matrix shown in Table 5a by highlighting the significant values calculated in the analysis. RCSI analysis measures the overall similarity among two or more localities based on the probable distribution or sharing of a fauna between those localities. The results show that significantly similar faunal pairs include (1) Wrangellia with Luning Allochthon and Alexander, (2) Stikine with Wallowa and Chulitna, and (3) Koryak with Eastern Klamath;

while slightly less similar pairs include, (4) Luning Allochthon with Alexander, (5) Quesnel with Eastern Klamath and Koryak, (6) Stikine with Eastern Klamath and Koryak, and (7) Wallowa with Chulitna. The significantly dissimilar faunal pairs include (1) Luning Allochthon with Eastern Klamath and Koryak, (2) Wrangellia with Eastern Klamath and Koryak, and (3) Alexander with Eastern Klamath and Wallowa.

Table 5a. RCSI analysis summary matrix of faunal similarity values based on species using 2000 sampling iterations. Locality symbols in Table 4.

	AL	**AN**	**CH**	**EK**	**KR**	**LA**	**QU**	**ST**	**WA**	**WR**
AL	1.000	.248	.500	.011	.140	.736	.248	.248	.112	.886
AN		1.000	.374	.248	.248	.308	.434	.434	.374	.248
CH			1.000	.500	.500	.640	.374	.871	.747	.500
EK				1.000	.886	.044	.752	.752	.500	.011
KR					1.000	.044	.752	.752	.500	.011
LA						1.000	.308	.308	.640	.961
QU							1.000	.434	.374	.248
ST								1.000	.871	.248
WA									1.000	.500
WR										1.000

Table 5b. Simplified RCSI faunal similarity matrix of Table 5a showing most significant values.

	AL	**AN**	**CH**	**EK**	**KR**	**LA**	**QU**	**ST**	**WA**	**WR**
AL				--	--	+			--	++
AN										
CH								++	+	
EK					++	---	+	+		---
KR						---	+	+		---
LA										+++
QU										
ST									++	
WA										
WR										

+++ = similarity ≅ 96% (greatly significant)
++ = similarity ≅ 87% (significant)
\+ = similarity ≅ 74%
--- = dissimilarity < 4% (greatly significant)
-- = dissimilarity ≅ 14% (significant)

MVSP. Figure 17 shows the results of running the MVSP, multivariate statistics package program. Although cluster analysis is a similar method to probabilistic faunal analysis, the results in this study show some differences. Results show generally two main clusters (defined as Jaccard coefficient >0.07), they are (1) the Luning Allochthon and Antimonio linked with Eastern Klamath, all linked with the Quesnel and Stikine cluster group and, (2) Alexander and Wallowa linked with Koryak. Chulitna has little similarity with the first cluster group and Wrangellia completes a cluster with the second cluster group.

PAUP. The parsimony analysis (PAE) was performed using the “Dollo-up” character in a heuristic search (Rosen, 1992). No outgroup was designated since “Dollo-up” implies polarity and therefore makes the use of an outgroup redundant. In the analysis, seven most parsimonious phylogenetic trees of length 107 and a consistency index of 0.505 were produced. Figure 18 shows a 50% majority-rule consensus of all seven trees generated. The groupings observed are as follows: (1) Stikine and Quesnellia together are sister areas, then with Antimonio, and all three link with (2) Chulitna and the Luning Allochthon, then the two groups link with (4) Eastern Klamath terrane to complete a branch of the tree; (4) Wrangellia and Koryak together are sister areas, then with Wallowa, and finally, (5) Alexander shows no relationship with any other terrane.

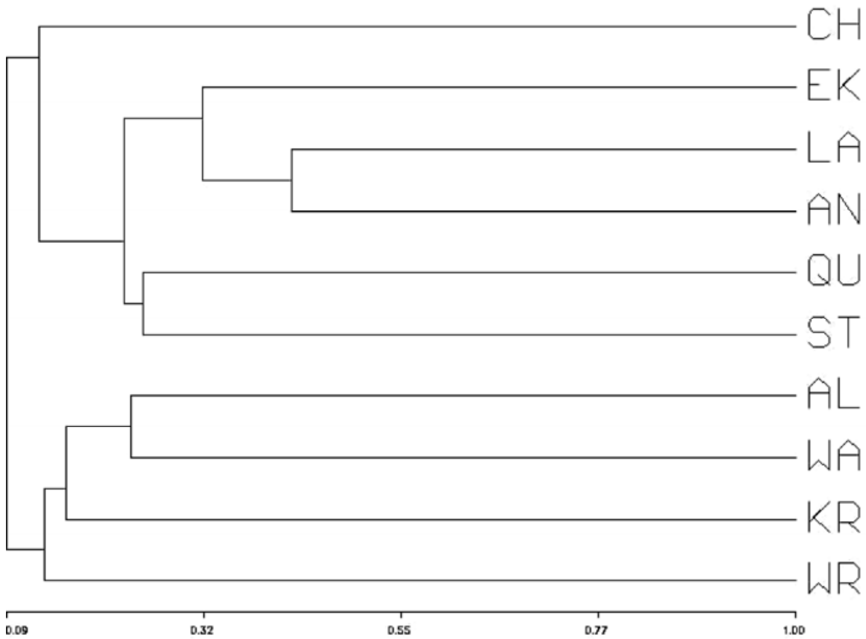

Figure 17. Results from the MVSP cluster analysis using the Jaccard coefficient.

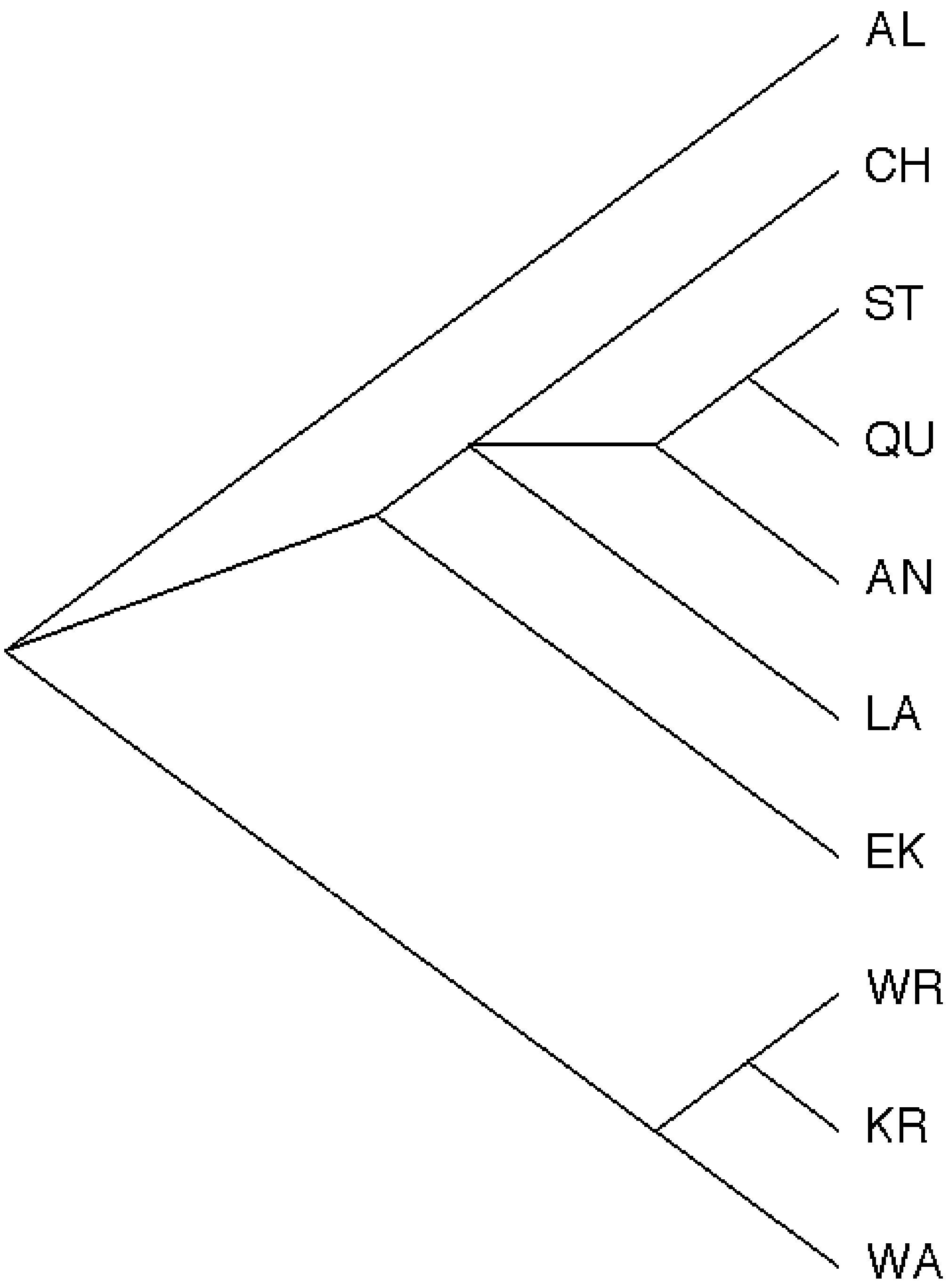

Figure 18. PAUP Phylogram depicting a 50% majority-rule consensus of seven most parsimonious trees with a length of 107 and a consistency index of 0.505.

Discussion

Probabilistic and cluster analyses generally produce similar results because they measure overall similarity. However, probabilistic analyses differ from cluster methods in that they “take into account the effect of sample sizes on similarity values, the randomness of sampling, the probability of occurrence of a taxon in a sample in relation to another taxon, and the relationship between sample sizes and population sizes” (Shi, 1993, p. 207). Probabilistic methods are therefore likely to show important relationships not shown by cluster analysis due to differences in sampling size among localities (Hanger, 1996). As a result, in probabilistic analyses, significant similarity or dissimilarity between localities indicates sufficient sampling of those localities and, thus, should be considered a “rough measure of sampling” (Hanger, 1996, p. 108). In this approach, probabilistic analysis shows significant similarity or dissimilarity between almost all localities, suggesting that they are generally well sampled and should be considered in statistical analyses.

The probabilistic analysis shows a pattern of “grouped” terranes, indicating possible sharing of fauna within a group, and therefore close potential geographic proximity to one another. Localities WR and LA show high similarity and AL also shows similarity to WR. Both WR and LA show high dissimilarity with EK and KR, and also AL is dissimilar with EK and KR. These relationships show a pattern in which, WR, LA, and AL are interpreted to have interacted during the Late Triassic, and probably shared fauna with one another more readily than with the other terranes. Relationships among the remaining seven terranes are also apparent. ST shows significant similarity with CH and WA, and minor similarity with EK and KR. This may indicate that ST was in a central position relative to the remaining terranes. KR shows significant similarity with EK and minor similarity with QU, which also has minor similarity with EK. Since QU relates to both KR and EK, it is then assumed that QU also existed in proximity to ST. AN shows neither similarity nor dissimilarity with any terrane, suggesting either geographic isolation or poor sampling.

Cluster analysis measures similarity and hierarchical relationships to produce both similar and different results in the probabilistic analysis. The grouping of EK, QU, and ST linked with CH to form a main branch of the cluster dendrogram agrees with probabilistic results that generally group these terrane faunas together. In the cluster analysis, unlike the probabilistic analysis, LA clusters with AN and occurs in the same group as EK, QU, and ST, and both KR and WA occur with WR and AL. This may indicate, when the probabilistic and cluster results are compared, that LA, AN, WA, and KR all occurred at a paleolatitude between the EK-QU-ST group and the AL-WR group. Although in the probabilistic analysis both CH and WR showed similarity to other terranes, in the cluster analysis, each occurs on a periphery branch of a main group, suggesting they existed a location near the outer edges of the geographic extent of the terranes. These results show that more than one analysis is needed to reveal all possible relationships. The clustering of KR and WA with the AL-WR group and LA with the EK-AN-QU-ST group (Fig. 17) presents completely different results from the probabilistic analysis which shows “dissimilar” relationships among these localities (Table 5b). Another difference shown in the cluster analysis is the placement of AN in the EK-LA-QU-ST group. In this case, since the probabilistic results do not support or refute this association, it must be considered a plausible relationship.

Although parsimony analysis of endemicity (PAE) is a relatively new method in terrane reconstruction, it can generate “area clades” that are considered hypothetical areas of genealogy and therefore should be used along with other statistical methods. In PAE, sister areas are considered to represent recency of biotic contact and thus, geographic closeness, whereas divergence of assemblages symbolizes divergence, or isolation of areas. Drawn as a phylogram, the results for PAE are a kind of family tree that depicts the derivation or evolution of (in this case) each terrane. In the phylogram, each intersection, called a node, indicates the point where one lineage splits to give rise to another. PAE results in this analysis, shown in Figure 18, illustrate at least three significant sets of terrane “evolution” lineages. These groups include: (1) sister areas ST and QU linked with AN, then with LA and CH, and then with EK to complete one branch, (2) sister areas WR and KR linked with WA to complete a second branch, and finally, (3) AL forming a third branch by itself. Since AL occurs by itself, it is implied that no biotic contact with other terranes occurred, and may be interpreted to have evolved, or developed, separately at a more outboard position relative to the terranes.

All three analyses produced both concurring and conflicting results. However, there are some patterns that generally repeat throughout each analysis. There appears to be an overall faunal relationship between the group AN, EK, LA, QU, and ST, which then has a kind of peripheral relationship with EK and CH. AL shows some conflicting relationships in all three analyses. This may indicate that AL evolved separate from the other terranes and had only minimal interaction with them. There is only a slight association between AL and WR, which makes questionable the convention of positioning these two terranes together during the Triassic. KR and WR have a conflicting relationship, showing dissimilarity in the probabilistic analysis, but similarity in the PAE. KR also shows similarity with EK, QU, and ST in the probabilistic analysis, but then links clearly with WR and WA in the cluster and PAE analyses. Perhaps KR was derived from or near WR and WA (as shown by PAE), but then diverged and moved to a position that increased faunal sharing with the other terranes.

The exact geographic position of North American displaced terranes may never be resolved, but it is possible to distinguish spatial relationships among them. When used in conjunction, probabilistic faunal similarity data, cluster analysis, and parsimony analysis of endemicity (PAE) reveal convincing patterns for terrane reconstruction. Figure 19 illustrates a paleogeographic reconstruction of the Cordilleran terranes that is based on the results of this study and supported by the following concepts taken from the literature.

- Hillhouse (1977) reported a paleomagnetic signature in Middle to Late Triassic basalts indicating a paleolatitude of 15 - 18° N or S for the northern Wrangel terrane.
- Speed (1978) proposed a position close to the craton margin for carbonate deposits in Nevada (Luning Allochthon) in the Late Triassic.
- Paleomagnetic data for Wallowa terrane indicates a Late Triassic paleolatitude of 18° ± 4° (Hillhouse et al., 1982).
- Tozer (1982) estimated positions for the Wrangell and Stikine terranes within 30° of the Triassic equator.
- Newton (1983) noted the lack of similarity between the Alexander terrane and the craton based on observation of bivalves, and suggested it was positioned outboard of Wrangellia.
- Newton (1987) reported faunal links between bivalves of North America and Wallowa terrane, suggesting Wallowa occupied a more easterly position relative to the other terranes.
- Hawley et al. (1987) reported the presence of quartzose clasts in the Late Triassic red beds of Chulitna, and suggested this indicates that the terrane was adjacent to a continental land mass during this time.
- Stanley and Whalen (1989) suggested a paleogeographic relationship between the Koryak terrane in Siberia, Wrangellia, and Wallowa based on similarity of Triassic coral and spongiomorph faunas.

- Stone and McWilliams (1989) analyzed paleomagnetic data for many Cordilleran terranes and reported the following “expected” paleolatitudes during the Triassic: Alexander (205-245 Ma), 28°N; Chulitna [correlative(?) to locality in source called “Wrangellia”, occurring in Healy-Mt. Hayes region] (205-225 Ma), 37°N; Luning Allochthon (208-230 Ma), 9°N; Quesnel (160-200), 27°N; Stikine (210-230 Ma), 28°N; Wallowa (208-230), 15°N; Wrangellia north (205-225 Ma), 35°N.

- The Antimonio terrane currently exists at a low latitude, west of the Mojave-Sonora Megashear, a postulated major left-lateral structural disconformity as discussed by Stanley et al. (1994). Following this reasoning, the Antimonio terrane must have originated at higher paleolatitudes near the craton and then moved tectonically along a left-lateral trend to lower latitudes (González-León, 1997).

- Stanley et al. (1994) noted faunal similarity and thus possible geographic proximity between the Antimonio and Luning Allochthon terranes.

- Belasky and Runnegar (1994) calculated faunal similarities and diversity trends for the Eastern Klamath terrane, Stikinia, and Wrangellia to reconstruct a probable Early Permian paleogeographic reconstruction of all three terranes. Their results put Eastern Klamath and Stikinia close to each other at about 25° N, 6700 km west of the craton and Wrangellia to the southeast of these terranes, at about 20° N, and less than 5000 km west of the craton.

- Monger (1996) depicted the Wrangellia, Stikine, and Quesnel terranes situated along a postulated arc at about 40°N latitude during Late Triassic to Middle Jurassic time (ca. 210 Ma.), implying these terranes were moving northward from slightly lower latitudes before the Jurassic.
- Aberhan (1998) reported faunal similarity trends between Early Jurassic bivalves of Stikinia and Wrangellia, suggesting geographic proximity of the terranes throughout the Early Jurassic as they moved northward.

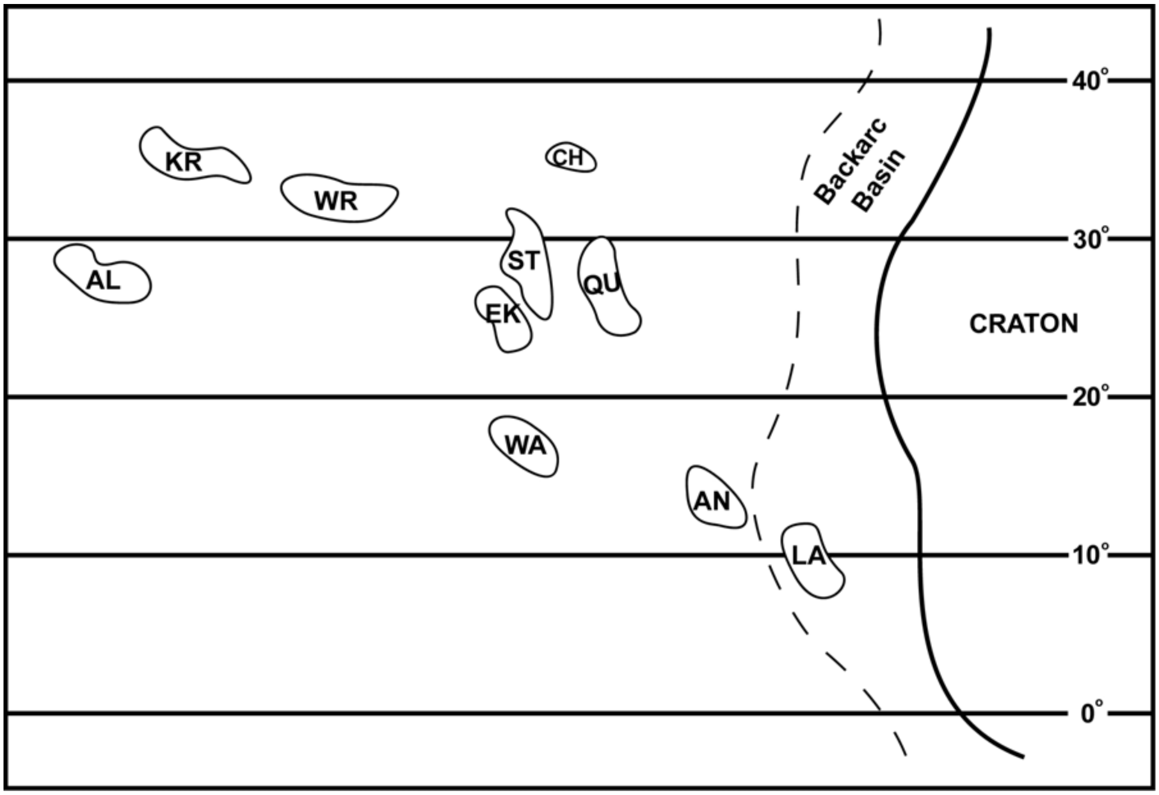

Figure 19. Schematic reconstruction of Late Triassic terrane paleogeography interpreted from the statistical results of this thesis and data from the literature. Note that terrane paleolongitude and size are exaggerated, and only the northern Wrangell terrane is depicted.

CHAPTER VI

CONCLUSIONS

Fossils from the Stikine and Chulitna terranes have paleogeographic significance when they are used to reconstruct the geographic relationship of outboard and inboard terranes in the western North American Cordillera. The purpose of this thesis was to demonstrate that thorough sampling and detailed taxonomic identification of fossils coupled with the application of multiple statistical paleobiogeographic analyses are important tools for testing hypotheses of terrane paleogeography. Prominent conclusions resulting from this study about the Late Triassic position of the Stikine and Chulitna terranes, their relationship with neighboring terranes, and the validity of established paleogeographic data are summarized below:

- Modern as well as ancient reefs, contain an abundant and diverse marine fauna. Therefore, paleobiogeographic analysis is not limited to fossil corals alone. Other well-studied fossil reef taxa such as bivalves, brachiopods, and sponges can be incorporated into similar studies for the Permian through Jurassic. Paleobiogeographic analysis of these taxa will not only support or refute the results of this study, but they will perpetuate and refine the methods used, thus improving the science of paleobiogeography.
- In theory, interpretive methods using paleontology for terrane reconstruction produce some degree of error due to the inherently problematic nature of fossil data. Therefore, it is important to utilize multiple analytical approaches

in order to formulate suitable conclusions. The patterns of terrane relationships revealed by probabilistic similarity, cluster analysis, and PAE are significant when the results are compared with established paleomagnetic, stratigraphic, and tectonic data. This study shows that multiple statistical methods, when used in paleobiogeographic analysis, can and do agree with other interpretations and conclusions about terrane paleogeography. This proves the validity of these methods as significant tools for reconstructing the Earth's history.

Although results from the probabilistic faunal similarity analysis seem to differ from both cluster analysis and PAE, notable patterns suggesting geographic proximity of groups of terranes exist throughout all three analyses and among the bivalve faunas.

- One significant conclusion from the probabilistic analysis is that there is a general grouping of Stikinia and Quesnellia with Chulitna and the Eastern Klamath terrane. This generally supports other paleogeographic interpretations that place Stinkinia in close geographic proximity to the Quesnel and Eastern Klamath terranes (Monger, 1996; Belasky and Runnegar, 1994; Aberhan, 1998). The Stinkine-Quesnel-Eastern Klamath-Chulitna grouping also appears in the cluster analysis and PAE, again suggesting these terranes were in proximity to one another during the Triassic. Results from cluster analysis greatly resemble results from PAE.

They show groupings of areas that I interpret to indicate different assemblages of terranes along or close to individual island arc chains in the Paleo-Pacific. In this hypothetical, most parsimonious interpretation (Fig. 19), Stikinia and Quesnellia lie together as inboard terranes near the craton, possibly associated with a major island arc. This arc is flanked by other inboard terranes, Chulitna to the north, the Luning Allochthon to the south, and by the Eastern Klamath and Antimonio terranes placed, respectively, to the west and southeast of Stikinia.

- The Koryak and Wrangellia terranes existed as outboard terranes, possibly along an island arc during the Late Triassic. Meanwhile, the Alexander terrane developed separately on its own, far removed from the craton, having little to no faunal similarity with other terranes or the continent. Sometime after the Late Triassic, the Koryak terrane moved westward towards Siberia as Wrangellia and Alexander moved toward the north to northeast.
- The Chulitna terrane covers a geographically small area (about 400 km^2) compared to most other Cordilleran terranes and it is often considered an orphan, displaced from a larger parent terrane. Stratigraphic comparison of Chulitna with Wrangellia and the Cache Creek terrane (Jones et al., 1982) shows distinctly different geologic histories, suggesting no geographic relationship between Chulitna and its neighboring regions. Analysis of Late Triassic red beds in the Chulitna terrane shows links to the North American craton, suggesting a near-continent position at that time. Results of the paleobiogeographic faunal analyses presented in this thesis, place Chulitna in

geographic proximity to Stikinia and Quesnellia. In particular, the probabilistic analysis (RCSI) shows similarity between Chulitna and Stikinia (Table 5b), which suggests that Chulitna may actually be a fragment of the Stikine terrane. Since both Stikinia and Quesnellia are also thought to have formed near the craton, an association with the Chulitna terrane is plausible.

- Apart from the corals, wallowaconchid bivalves also have paleobiogeographic significance. The wallowaconchids found at Lime Peak, Yukon, in the Stikine terrane, are conspecific with the type species described from the Wallowa terrane in Oregon. However, the wallowaconchids described from the Chulitna terrane are morphologically most similar to those found in the Antimonio terrane of Sonora. These observations suggest geographic connections between Stikinia and Wallowa, as well as between Chulitna and Antimonio. The paleogeographic reconstruction shown in Figure 19 supports this interpretation.

When the results from the statistical analyses are combined with paleogeographic data from the literature, some inconsistencies were revealed.

- Paleomagnetic data for the Wrangell terrane reported by Hillhouse (1977) differ from those reported by Stone and McWilliams (1989). The statistical results generated in this analysis seem to agree more with the data from Stone and McWilliams (1989). This conclusion is based on the inferred close geographic relationship between northern Wrangellia and higher paleolatitude terranes such as the Koryak and Alexander terranes. Likewise, little to no similarity is shown with the Luning Allochthon, a lower paleolatitude terrane. Therefore, I suggest that the northern portion of Wrangellia originated at higher paleolatitudes, probably near those proposed by Stone and McWilliams (1989).

- Little to no faunal similarity occurs between the Alexander and Wrangellia terranes. This is problematic when considering other geologic data. Gardner et al. (1988) reported that northern Wrangellia and the Alexander terrane were sutured together as early as Pennsylvanian time, based on the occurrence of pluton stitching between the two terranes. This relationship is not shown by the results of the paleobiogeographic analyses of this thesis and may need further exploration both geologically and paleontologically.
- The Wallowa terrane shows similarity with the Koryak terrane and Wrangellia, but paleomagnetic data, similarity of wallowaconchid bivalves with Stikinia, and links to the craton make its relationship with Wrangellia and geographic placement during the Late Triassic problematic. Stratigraphic comparison of Wallowa with Wrangellia by Sarewitz (1983) also questions the origin of the Wallowa terrane, which was commonly thought to be a fragment of Wrangellia. Future research may reveal that other factors such as direction of ocean currents carrying coral and bivalve larvae or faunal exchange facilitated by geographic proximity to other terranes not analyzed in this study may account for the discrepancies of the Wallowa terrane.

- Placement of the Antimonio terrane is also problematic. Stanley et al. (1994) noted faunal similarity between Antimonio and the Luning Allochthon, suggesting Antimonio originated near the North American craton. However, the presence of an unofficially identified, but similar wallowaconchid bivalve species from Sonora, Mexico relates the Antimonio terrane to Chulitna, another high paleolatitude terrane. The statistical results also indicate similarity between Antimonio and the Stikine-Quesnel terrane group. It is probable that the Antimonio terrane developed at a geographic position between the Stikine-Quesnel terrane group and the Luning Allochthon. As a result, the paleogeography of the Antimonio terrane remains questionable and awaits further paleontologic, paleomagnetic, tectonic, and stratigraphic analysis.

- In conclusion, paleobiogeographic analysis using probabilistic, cluster, and PAE methods provides a stable, scientifically sound stepping off point for future terrane reconstructions and opens a window to life in the past. In particular, the results of this study are based on well-founded scientific and biologic principles and they encourage continued evaluation of North American and Siberian faunal relationships throughout the Paleozoic to Mesozoic. Paleobiogeography contributes valuable insight into the reconstruction of North American terrane paleogeography and, in doing so, may ultimately lead to a better understanding of faunal recovery after mass-extinction and of reef evolution along the western North American margin.

The sixteen coral, two bivalves, and one spongiomorph identified in this study reiterate the fact that rich assemblages of Late Triassic coral and other reef fauna occur, not only in the former Tethys region, but also in the displaced terranes of North America. Such an abundance of fossil data has great potential for reconstructing and testing terrane paleogeography. It is hoped that the results from this study will invite continued investigation of Triassic marine deposits, such as those at Lime Peak, Yukon and Long Creek, Alaska, as well as the search for new localities. Similarly, alternative methods for reconstructing terrane paleogeography such as the statistical approach taken in this thesis are meaningful and should be considered for use with different fossil faunas, time periods, and areas of the world. This thesis illustrates that applying statistical methods to analyze paleontological data in order to determine paleogeographic relationships is an integral part of terrane analysis. The true paleogeography of North American displaced terranes may never be known, but when the results of statistical analyses are integrated with established paleomagnetic, stratigraphic, and tectonic data, the conclusions are intriguing and encourage future research utilizing statistics for paleobiogeographic terrane reconstruction.

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Appendix A:

Criteria for the Selection of Data

The following criteria were used in the selection of data in order to homogenize the data set and thus constrain the results temporally and spatially (many of the suggested parameters are arbitrary and are specified in this thesis only to limit the data set).

1.) **Locality:** The locality must contain fossil coral and occur in a displaced terrane of the North American Cordillera.

2.) **Environment:** The fossil coral must be associated with reef or reef buildup deposits. In most cases the fossils will occur in reef limestone or carbonates.

3.) **Age:** The stratigraphic age of the coral horizon must be Late Triassic Norian.

4.) **Sampling:** The fossil locality must be adequately sampled and documented. At least five or more coral species should be present.

5.) **Valid Identifications:** The fossil coral taxonomic identifications must be considered valid and contemporary, and should be placed in synonymy with other published material.

Appendix B:

Description of Cordilleran Terrane Localities Containing Triassic Coral

The following is a description of the eight Triassic localities used along side Lime Peak and Long Creek in the analytical portion of this thesis. Each locality is described with respect to the displaced terrane in which it occurs. All localities are generally considered well documented, accurately dated, and sufficiently sampled for scleractinian corals.

Alexander terrane

Late Triassic corals in the Alexander terrane are found on Gravina Island, located in southeast Alaska. Smith (1927) first described Triassic corals from Gravina Island, followed by Stanley (1979) and Montanaro-Gallitelli et al. (1979). Stanley (1979) notes the occurrence of the bivalve *Halobia* in strata also containing coral and confirms an Early Norian age to this locality. Fossils were collected from Nehenta Bay or Threemile Cove (Smith, 1927; Stanley, 1979) and Fivemile Cove (Smith, 1927).

Antimonio terrane

Stanley et al. (1994) first described fossil coral from the foothills of the tectonically allochthonous Sierra del Alamo, in northwestern Sonora. The coral occur in the Antimonio Formation, a 3.4 km-thick stratigraphic succession that records deposition of Upper Triassic to Lower Jurassic sedimentary rocks. Tozer (1982) described the Antimonio block as a displaced terrane and suggested a low-latitude paleogeographic position during the Triassic. Most of the fossil material studied were collected from Sierra del Alamo, west of Caborca (Stanley et al., 1994).

Eastern Klamath terrane

The Eastern Klamath terrane is located in the Klamath Mountains area in Shasta County, northern California. Late Triassic corals were first reported and described by Smith (1912, 1927) from Hosselkus Limestone outcrop beds found along the Pit River. Stanley (1979) determined an Early Norian age for this locality, based on the occurrence of corals above strata containing the Late Carnian ammonoid species *Tropites welleri* and below Rhaetian ammonoids. Fossils were collected from Brock Mountain, the north fork of Squaw Creek, the junction of Cedar Creek and Little Cow Creek (Smith, 1927), and at Squaw Creek Ranger Station (Stanley, 1979).

Koryak Highlands terrane

The Koryak terrane is a displaced tropical volcanic island block located within the Kenkeren Range of northeastern Siberia. Triassic scleractinian coral discovered in Norian reef-associated carbonate deposits suggest that this terrane originated at lower paleolatitudes in the Paleo-Pacific. Aside from the presence of Triassic scleractinian coral, other marine fauna such as the bivalves *Halobia* aff. *brooksi* and *Cassianella* sp. indicate a Late Triassic (Norian) age for the deposits. The terrane is considered to have been part of the former Tethys region.

Luning Allochthon

Smith (1912) first reported fossil corals from the Luning Formation located in Dunlap Canyon in the Pilot Mountains of the Luning Allochthon in west-central Nevada. Investigations of the area by Smith (1927) and Muller (1936) produced systematic descriptions of a rich Triassic marine faunal assemblage. Silberling and Tozer (1968) determined a Norian age for the reef buildups in the Luning Formation. Stanley (1979) later assigned an Early Norian age between the Kerri and Magnus zones.

Quesnel terrane

The Late Triassic fossil coral locality in the Quesnel terrane is at a site called the "Eaglenest reef" (Nelson et al., 1993), described from the Kwanika Creek map area in central British Columbia. The Eaglenest reef locality contains a light-colored, massive, reef-like limestone that is exposed in a cliff-face at a thickness up to 200 m. The limestone unit belongs to the Plughat Mountain succession and is dated Upper Triassic Norian to middle Norian by the conodonts *Neogondolella* cf. *navicula*, and *Neogondolella* cf. *steinbergensis* (Stanley and Senowbari-Daryan, 1999). The coral fossil were collected from the stratigraphic top of a bedded, sponge- and coral-dominated limestone unit found along the eastern margin of Eaglenest reef.

Wallowa terrane

Two localities containing Late Triassic fossil coral are known from the Blue Mountain Province in northeast Oregon and adjacent Idaho. Corals were first collected and described by Smith (1927) from the Martin Bridge Formation which crops out along Eagle Creek in the Blue Mountains. Stanley (1979) revisited

Smith’s site as well as several other localities and later illustrated and systematically described the material he collected (Stanley, 1986). Based on Smith’s (1927) observation of *Halobia halorica* and *H. dilatata* in the shale above the coral horizon of the Martin Bridge Formation beds near Eagle Creek, as well as work by Silberling and Tozer (1968), Stanley (1979) assigned and early Norian (=Kerri Zone) age for the coral interval.

Another fossil coral locality of the Martin Bridge Formation occurs along the Snake River, in Hells Canyon at the border of Oregon and Idaho (Vallier, 1967). Montanaro-Gallitelli et al. (1979) identified corals from this locality which were later revised by Stanley (1986) and then examined thoroughly by Stanley and Whalen (1989). The presence of the ammonite *Trophiceltites* cf. *T. columbianus* in the coral horizon indicates an age of Early Norian (= Kerri-Magnus Zone) (Vallier, 1967; Stanley and Whalen, 1989).

A third coral fossil locality that is tentatively placed within the Wallowa terrane is at Lewiston, Idaho, in a limestone quarry on the east side of Mission Creek on the Lapwai Indian Reservation. Squires (1956) first reported on the corals from this site. Later, Stanley (1979, 1986) conducted investigations of this locality and revised some of the early interpretations made by Squires (1956). The Lewiston, Idaho is generally considered a subset of the Blue Mountains Range, but it is unclear if the deposit is correlative with the Martin Bridge Formation. Squires (1956) reported a Norian age for the site, based in previous reports on the stratigraphy by Cooper (1942). Stanley (1979, 1986), however, suggested a latest Rhaetian age (= Crickmayi Zone) because of the similarity of the coral fauna with assemblages found in southern Vancouver Island. This assumption is unconvincing since the coral assemblage also shows similarity to other Norian coral localities in North America (see Table 2). Therefore, in this thesis, the locality is considered at least Norian in age based on stratigraphic observations.

Wrangell terrane (north)

Fossil coral in the Wragell terrane occur in two different localities, the Wrangell Mountains, Alaska and Lake Cowichan, Vancouver Island, British Columbia. They are generally referred to as Wrangellia north and Wrangellia south, respectively. Because Wrangellia south is considered Rhaetian (= Crickmayi Zone) in age, it was not used in this study (see Appendix 1). Fossil coral occur in the north Wrangell terrane in the Chitistone Limestone at a site called Green Butte located within the Wrangell Mountain Range in southeast Alaska. Montanaro-Gallitelli et al. (1979) first studied material collected from this site, which later was revised by Stanley (1986, 1989) and Prinz (1991). The Chitistone Limestone contains a coral- and spongiomorph-dominated biostrome which is dated Early Norian (= Kerri Zone) by the ammonite *Trophiceltites* cf. *T. columbianus* and the bivalve *Halobia brooksi* (Silberling and Tozer, 1968).