Upper Triassic carbonates and Scleractinian corals from Wrangellia and the Alexander Terrane (Alaska and Vancouver Island Canada): Depositional environments and paleobiogeography

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UPPER TRIASSIC CARBONATES AND SCLERACTINIAN CORALS FROM WRANGLELLIA AND THE ALEXANDER TERRANE (ALASKA AND VANCOUVER ISLAND, CANADA): DEPOSITIONAL ENVIRONMENTS AND PALEOBIOGEOGRAPHY

By

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Approved by

Chairperson

Dean, Graduate School

11/30/05

Date
Taxonomic identification of Upper Triassic (Norian to Rhaetian) silicified shallow-water corals were used to analyze paleobiogeographic signatures and to test Carboniferous amalgamation of Wrangellia and the Alexander terrane, Alaska and Vancouver Island Canada. Analysis suggests similar coral faunas between southern Wrangellia (Vancouver Island) and Peru (Pucará Group). Dissimilar coral faunas were found between northern and southern Wrangellia, the Alexander with the Wallowa terrane and northern and southern Wrangellia and the Wallowa terrane with Peru. Phylogenetic trees showed groupings consistent within localities from the Alexander terrane, and southern Wrangellia. Southern Wrangellian localities are distantly grouped with fauna from Peru, northern Wrangellia and the Wallowa terrane. Therefore, paleobiogeographic analysis does not support amalgamation between Wrangellia and the Alexander terrane during the Triassic.

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Chapter I: Introduction

(I) Purpose of Study

The overall purpose of this thesis is to determine the Upper Triassic (Norian) paleobiogeography of Wrangellia and the Alexander terrane using a compiled data set of coral genera and species. Statistical comparison of similarity was performed to test a hypothesis suggesting the amalgamation of Wrangellia with the Alexander terrane during the Carboniferous. Paleobiogeographic analysis was aided by litho and biofacies comparisons and paleoecologic interactions of silicified corals, sponges and spongiomorphs within localities of Wrangellia and the Alexander terrane. Paleobiogeographic results established within this thesis also were used for statistical comparison with the Wallowa terrane and the Pucará group, Peru.

(II) History of Displaced Terranes

The Early Triassic was marked the breakup of the super continent Pangea (Figure 1), resulting in massive global change (Flügel, 2002). Tectonic forces separated these massive cratonic blocks throughout Middle and Upper Triassic time. These forces were also responsible for the reconfiguration of oceanic basins, affecting global water current dynamics, climate change, and ultimately suitable reef settings (Flügel, 2002). The breakup of Pangea splintered the pre-existing craton into fragments that were spread throughout the newly opening Tethys Sea (Flügel, 2002). Subduction also created many volcanic island arcs spread throughout the Tethys Sea and Panthalassan Ocean (Tozer et al., 1991).

These splintered continental fragments and volcanic island arcs are known today as tectonic terranes and are the focus of this thesis; specifically, the paleogeographical
Figure 1 – Global reconstruction of continental positions during the Triassic time period featuring Pangea and the newly forming Tethys Sea. (Adapted from http://ian.ucc.nau.edu/~rcb7/Trias.jpg)
implications using faunal assemblages of corals within previously established terrane boundaries. Terranes are defined as, “Fault-bounded bodies of rock of regional extent, characterized by a geologic history different from that of contiguous terranes or bounding continents. A terrane is considered to be a discrete allochthonous fragment of oceanic or continental material added to a craton at an active margin by accretion (Jackson, 1997).” Terranes, which record a unified tectonic history (Coney et al., 1980; Tozer et al., 1991), are characterized by internally consistent lithology, fossils, and stratigraphy.

Terranes also contain differences in faunal assemblages (biofacies), rock sequences (lithofacies) and have paleomagnetic records that differ from surrounding terranes as well as the adjacent craton (Coney et al., 1980). Several geographical boundaries have been established throughout the Cordillera by using these apparent discontinuities (Jones et al., 1977, Coney et al., 1980; Jones et al., 1982; Gehrels and Saleeby, 1987), the study of which helps to accurately reconstruct the extensive geological history of Western North America.

An understanding of gross tectonism and paleoecologic interactions between terranes may be developed by studying their paleobiology. Within the Upper Triassic strata, unique faunal assemblages have been recognized from various North American Cordilleran localities (Clapp and Shimer, 1911; Smith, 1927; Squires, 1956; Montanaro Gallitelli et al., 1979; Stanley, 1979; Stanley 1986, 1989; Stanley and Whalen, 1989; Yarnell, 2001). These Upper Triassic faunal assemblages extend from central California to central Alaska and encompass a few cratonic localities as well. Terrane assemblages have been used, in part, to define and compare paleobiogeography from the Late Paleozoic to Late Mesozoic time.
(III) Paleogeography

Paleogeography is the study of ancient geography and is ultimately used in this thesis to approximate the geographic location of an area (or terrane) during a particular time interval. This is possible by comparing statistically similar paleofaunas within terrane boundaries to previously established paleomagnetic results in order to establish tectonic patterns for terranes. Changing patterns of biogeography can indicate tectonic displacement through time, climate change, differences in spatial and temporal distributions of fossils, as well as find geographic proximity between terranes (Raup and Crick, 1979; Belasky and Runnegar, 1993, 1994; Aberhan, 1999). Paleomagnetic analysis is defined as being, “The study of natural remanent magnetization of Earth materials in order to determine the intensity and direction of the Earth’s magnetic field in the geologic past” (Jackson, 1997). By studying paleomagnetic properties, paleolatitudes are established within terrane boundaries. Paleolatitudes determine paleogeographic position for the parent igneous rock body at time of deposition. Paleomagnetic analysis of the Cordilleran terranes suggest that throughout the Triassic, terranes were displaced thousands of kilometers and in some cases even rotated significantly in comparison to the North American craton, which was also moving (Irving and Yole, 1972; Hillhouse, 1977; Hillhouse and Grommé, 1980; Butler et al., 1997).

(IV) Alexander and Wrangellia Terranes

The Alexander terrane and Wrangellia are located in southeast and south-central Alaska as well as on Vancouver Island and other parts of western Canada (Berg et al., 1972; Jones et al., 1972, Gehrels and Saleeby, 1987, Jones et al., 1977). They are two of many displaced terranes lying adjacent to each other helping to comprise the Cordilleran
region of Western North America and Canada (Figure 2). Prior to accretion, the Alexander and Wrangellia terranes, are considered to have been island-arc systems located in the Panthalassan Ocean (Coney et al., 1980). However, local lithology suggests these two terranes have undergone considerably different tectonic histories throughout the Phanerozoic (Berg et al., 1972; Jones et al., 1972). Both terranes contain stratigraphy consisting of volcanic and sedimentary rocks that are Cambrian through Middle Jurassic age, with comparable Upper Triassic reef assemblages surrounding them (Gehrels and Saleeby, 1987; Gardner et al., 1988; Stanley, 1993; Soja, 1996).

The Alexander terrane is considered to be a displaced continental fragment based on a foundation of Late Proterozoic to Early Paleozoic continental crust (Berg et al., 1972; Jones et al., 1972). The Alexander terrane is further unique because it contains volcanic and sedimentary rocks from every Phanerozoic system, making it ideal for study and interpretation. The Alexander terrane was a separate entity throughout much of its Paleozoic history (Wilson, 1968; Monger and Ross, 1971; Jones et al., 1972; Monger et al., 1972; Hillhouse and Grommé, 1980; Newton, 1983; Butler et al., 1997; and Belasky et al., 2002). It contains similar aged rocks to those of adjacent Wrangellia but differ in lithologic, paleomagnetic and paleobiogeographic properties (Jones et al., 1977).

In contrast to the Alexander terrane, Wrangellia is principally composed of fragmented and separated sub-blocks that stretch nearly 200 km along the western coast of North America (Jones et al., 1977). The northern block contains the type section in southern Wrangell Mountains of south-central Alaska. The studied area of the southern block lies on Vancouver Island western British Columbia, Canada (Figure 2). Two smaller sub-blocks (Figure 3), that constitute the Queen Charlotte and Chichagof islands,
Figure 2 – Generalized map of western North America showing approximate positions of Wrangellia and the Alexander terrane. (Modified from Jones et al., 1972; Jones et al., 1977; and Katvala 2004)
have also been included in this terrane (Jones et al., 1977) but have been excluded from this study. Jones et al. (1977) group all four blocks and sub-blocks of this terrane together by internally consistent Triassic lithologic sequences (Figure 3).

The type section in northern Wrangellia contains a Triassic stratigraphic succession that is quite similar to each of the other four blocks and sub-blocks of this terrane (MacKevett, 1976; Jones et al., 1977). Mackevett (1976) and Armstrong and Mackevett (1982) described the lithological sequence of northern Wrangellia as beginning with a layer of bedded chert (middle Ladinian) overlain by the Nikolai Greenstone, a thick volcanic unit intermixed with pillowed aa and pahoehoe basalt. The basalt is disconformably overlain by a carbonate sequence about 1400 m thick of the Carnian to Norian Chitistone and Nizina Formations.

Triassic rocks of southern Vancouver Island contain stratigraphic sequences and lithologies strikingly similar to those of the northern block (Jones et al., 1977) (Figure 3). Muller et al., (1974) and Yorath (1999) show the base of the sequence begins with 200 m of black silicified shale and siltstone intruded by numerous middle Ladinian sills. This unit is overlain by approximately 6600 m of volcanic rock of the Karmutsen Formation containing: (1) pillow lava, (2) pillow breccia and aquagene tuff and (3) basalt flows with minor pillow lava and sedimentary layers. The volcanic unit is overlain by Norian to Early Rhaetian carbonate of the Quatsino Formation and limestone and shale of the Parson Bay Formation (Yorath, 1999).

Prior to the discovery of plate tectonics, Smith (1927) recognized Upper Triassic shallow-water marine invertebrate fossils from a variety of localities spanning the western coast of North America and Canada. From rock now regarded as Wrangellia and
Figure 3 – Correlative stratigraphic columns showing Middle – Upper Triassic rock sequences for localities within the recognized borders of Wrangellia. (Modified from Jones et al., 1977)
the Alexander terrane, Smith concluded these fossils comparable in age. They, along with rocks from other terranes were thought to represent fringing reefs spanning the entire western coast of North America. Later Stanley (1979) clarified the situation, putting Smith's coral and spongiomorph reef occurrences within the emerging concepts of terrane theory and thus explaining the high latitudinal anomalies. Without plate tectonic/terrane theory, Smith was at a loss to explain occurrences of the high latitudinal Alaskan reefs using present day models. Subsequent lithological, structural, paleomagnetic and paleontological work have separated these Triassic limestones into many different terranes, including Wrangellia and the Alexander terrane, interpreting their tectonic-magmatic histories and their post-Triassic accretion onto the North American craton.

Gardner et al., (1988) pointed out that the Pennsylvanian-aged plutons that cut both Wrangellia and Alexander terrane boundaries indicate these two terranes were amalgamated in the Carboniferous. Terrane amalgamation could also be indicated through similar geology, paleomagnetism and faunal composition including diversity and ecology (paleobiogeography). Jones et al., (1977) recognized distinctly different Triassic sequences between the Alexander and Wrangellia terranes, directly challenging an amalgamation during the Carboniferous. Paleobiogeographic studies utilizing the well-preserved faunas have yet to test the stitching hypothesis. Both terranes in question contain Mesozoic and Paleozoic fossils including bivalves, corals, sponges, spongiomorphs, brachiopods, and fusulinids, which offer independent ways to test the stitching hypothesis.

(V) Previous Paleobiogeographic Studies
Early paleobiogeographic study of reef-building rugose corals, suggest that during the Permian time period, Wrangellia was situated 5000 km west of the craton (Belasky and Runnegar, 1994). However, a more in-depth study using rugose corals, brachiopod and fusulinid faunas infer that during the Permian, Wrangellia and the Alexander terrane were situated approximately 2000 – 3000 km west of the North American craton (Belasky et al., 2002). Newton (1983) analyzed Upper Triassic bivalves from Wrangellia and the Alexander terrane and concluded that Wrangellia occupied an Eastern Pacific location, and was statistically similar to Upper Triassic (Lower Norian) faunas from Hells Canyon and cratonal North America. The Alexander terrane, on the other hand probably occupied a more southerly position during Upper Triassic time, having a Triassic bivalve in common with Peru. Aberhan (1999) also studied the paleobiogeography of the Early Jurassic bivalve *Weyla*. He determined that Wrangellia moved northward from several hundred to possibly more than 1000 km since the Early Jurassic. Further paleobiogeographic study of Upper Triassic corals by Yarnell (2001) suggests a high degree of similarity between Wrangellia and the Alexander terrane, which conflicts with lithologic and stratigraphic results of Jones et al. (1977).

A preliminary Upper Triassic paleobiogeographic summary of the Alexander terrane by Yarnell (2001) was based on older, out of date literature including coral data of Smith (1927). Many of Smith’s (1927) generic and specific identifications have been updated by Roniewicz (1989) in a new taxonomic scheme, based on microstructural differences among the corals. Furthermore, previous studies of Upper Triassic corals from the Alexander terrane only included a small subpopulation of specimens collected from the western coast of Gravina Island, and did not include any specimens from the
rich Upper Triassic deposits of Keku Strait (Katvala, 2004). Older coral samples were
collected as crack-out material, and therefore statistical accuracy of fossil data was
skewed and is in need of revision and up-dating in a more detailed study. Newer acid
etching techniques greatly enhance morphological detail and increases sample size for
better statistical results. Paleobiogeographic results in this thesis were generated from
systematic identification of previously collected and new Upper Triassic coral from many
localities within Wrangellia and the Alexander terrane.

(VI) Paleomagnetic Studies

Paleomagnetism is used to track the changing positions of terranes through time.
Paleolatitude results for the Alexander terrane yield 14°N +/- 4° in the Early Devonian,
25°N - 30°N in the Lower Permian and 10°N - 23°N in the Late Triassic (Hillhouse and
Grommé, 1980; Butler et al., 1997). On the other hand, Hillhouse, (1977) and Irving and
Yole (1972) indicate a lower paleolatitude, within 15° of the paleoequator, for both
northern Wrangellia in the Wrangell Mountains and southern Wrangellia on Vancouver
Island during the Triassic. Therefore, Wrangellia was closer to the equator than the
Alexander terrane during the Triassic and has since moved several thousand kilometers
northward relative to North America (which was also moving) in post-Triassic time
(Hillhouse and Grommé, 1980; Aberhan, 1999). Since the Triassic and Jurassic,
paleomagnetic records suggest the Alexander terrane did not move as far northward
relative to Wrangellia.

(VII) Inherent Biases of Statistical Tests

Previous studies have used a variety of multivariate statistical tests, parsimony
analysis of endemicity, as well as probabilistic estimates of diversity and similarity, to
reconstruct terrane paleogeography by comparing fossil faunas of different terrane localities (Henderson and Heron, 1977; Raup and Crick, 1979; Belasky, 1992, 1993, 1994, 2002). However, paleobiogeographic analysis carries inherent flaws that deserve attention. Henderson and Heron (1977) note that any paleobiogeographic study should 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) **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.”

(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.”

(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.”

(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 problems with using paleontology for paleogeographic analysis, Shi (1993) maintained that valid results can still be generated using multivariate statistical methods with computer application. Proper tests can sort through these relevant biases to reveal complex patterns within the fossil data.
(VIII) Significance of Reefs

According to Jackson (1997, p. 536) the term “Reef” has three main definitions: (1) “A ridge-like or mound-like structure, layered or massive, built by sedentary calcareous organisms, esp. corals, and consisting mostly of their remains; it is wave-resistant and stands above the surrounding contemporaneously deposited sediment. Also, such a structure built in the geologic past and now enclosed in rock, commonly of differing lithology. (2) A mass or ridge of rocks, esp. coral or shells and sometimes sand, gravel, boulder conglomerate, hogback ridges, dikes, or sills, rising above the surrounding sea or lake bottom to or nearly to the surface, and forming an obstruction to navigation. (3) A provincial term for a metalliferous mineral deposit, esp. gold-bearing quartz such as a saddle reef.” In addition Prothero and Schwab (1999) note that reefs grow within the wave zone, and have wave-resistant organic framework. Stanley (2001) differentiates these reefs into “biological” and “stratigraphical.” “Biological” or “ecological” reefs are composed of prolific biotic components that reflect complex interaction within a shallow-water setting. “Stratigraphic” reefs describe a thickened carbonate mass differing appreciably from surrounding rocks (Stanley, 2001). They may have had their fossils obliterated by recrystallization, dolomitization, or other diagenetic processes (Stanley, 2001). Mud mounds are another term associated with reefs, however, do not present biological framework necessary for classification as “biological” reefs, but do fit within the definition of “stratigraphical” reefs. The framework concept has been seriously challenged by Hubbard et al. (2001) who remarked on the taphonomy of Holocene reefs, the framework of which are frequently transformed into rubble by physical and biological processes.
I use the term “Reef” to describe an organic build-up of Upper Triassic corals, sponges and spongiomorphs as in definition (1).

Historically, carbonate reefs have been recognized and their characteristics plotted throughout the Phanerozoic (Kiessling et al., 2002); however, the quintessential framework of these reefs is highly variable, incorporating a multitude of organisms including; cyanobacteria, stromatolites, archaeocyathids, crinoids and blastoids, stromatoporoids, receptaculitids, tabulate, rugose and scleractinian corals, rudistid bivalves, brachiopods, coralline algae, bryozoans, and sponges.

Fossilized reefs have long been taken by sedimentologists as indicators for certain “Optimal” paleoenvironmental conditions of the tropics to subtropics (Prothero and Schwab, 1999). Reefs flourish best under conditions of optimal nutrients, sunlight, water temperature, and depth; and degrade under conditions of higher environmental stress, including increased sedimentation or volcanism (Stanley, 1988; Prothero and Schwab, 1999; Zonneveld et al., 2002; Flügel, 2002). Therefore, the presence of a reef indicates a multitude of environmental (biological and sedimentological) conditions. Equally important in reef ecosystems is photosymbiosis, especially when established between zooxanthellae and their coral hosts (Wood, 1999).

During the Upper Triassic (Norian to Rhaetian time), scleractinian corals, spongiomorphs and calcified sponges were the major reef-builders, and the paleotropics extended >30° N and 35° S of the paleoequator (Flügel, 2002). This produced a wide, warm and arid tropical band across the Upper Triassic Earth, promoting development of large-scale framework reefs, some Norian examples were over 2000 m thick (Flügel, 2002). These grew along rift-shoulders of the Tethys seaway across what is now central
Europe and Asia. In the Panthalassan Ocean, small-scale reefs and buildups sporadically occurred, surrounding continental fragments and volcanic island arcs situated within the eastern Tethys seaway and Panthalassan Ocean (Stanley, 1988; Zonneveld et al., 2002; Flügel, 2002). While terranes of the North American Cordillera geographically existed within the paleotropics during the Upper Triassic, we find little or no reef development. Stikinia, Quesnellia and the Wallowa terrane provide the only examples of Tethyan-type reef development, but in other tropical to subtropical terranes such as Wrangellia, there is little or no evidence of reefs. Even though the potential for reef development was there, Zonneveld et al. (2002) suggest higher rates of sedimentation and increased volcanism within these terranes was the most likely cause for the relative absence of reef ecosystems. This paper discusses corals and the situation with reefs in both the Alexander terrane and Wrangellia. Criterion for reef classification included in situ framework of organisms displaying definite structure within a laterally confined carbonate rock sequence.
Chapter II: Methods

(I) Field Methods

I visited the Upper Triassic carbonate rocks of the Parson Bay Formation
Vancouver Island, Canada summer 2002 and 2005; the Nehenta Formation on Gravina
Island southeast Alaska for six days during the summer of 2003 and eighteen days,
summer 2004; the Hyd Group in Keku Strait southeast Alaska for seven days, summer
2003; and two days in the Chitistone Limestone at Green Butte, Wrangell Mountains
southcentral Alaska. During field visits to southeast and southcentral Alaska, I collected
numerous paleontological samples, recorded a variety of lithologies and measured a
section.

Rocks comprising the Hyd Group of Keku Strait and Nehenta Limestone of
Gravina Island are well exposed within the intertidal zone. When venturing inland into
the temperate rainforest of southeast Alaska, outcrops are covered by dense vegetation
and foliage. Furthermore, a lack of roads or trails made access strictly limited to small
boats and/or hiking along the coast. The Chitistone / Nizina Limestone section at Green
Butte is extremely well exposed along the high mountain ridges and canyons. Vegetation
and ground cover exist only as short grasses and weeds that are situated between
limestone outcrops. Fossils are easily identifiable due to their well-silicified nature and
the fact that they have begun to weather-out from the surrounding limestone matrix. I
recorded sample locations with a hand held Garmin Legend GPS (Global Positioning
System) unit and topographic maps. A one meter long Pogo stick (separated into
decimeter increments) was used to measure section. I used acid etching at the University
of Montana paleontology laboratory to expose fossils.
Samples were collected for macrofossils as well as microfossils (principally conodonts). Conodonts are important in assigning relative ages for sedimentary rock units (Orchard, 1991). Limestone blocks containing macrofossils were collected based upon abundance (within the surrounding carbonate), silification and accessibility. Blocks that were not readily accessible were photographed and described in order to gather as much information as possible about the overall diversity. In areas of dense macrofossils, I collected conodont samples stratigraphically above and below the fossil beds.

I sampled for conodonts at different stratigraphic intervals while measuring the section. Samples were collected as close to the base of the section as possible and again periodically throughout while measuring and describing the section. Sample number largely depends upon the amount and purity of limestone interbeds that exist throughout the section. Samples weighed between 2-4 kilograms and were marked according to stratigraphic level within the section.

(II) Laboratory Methods

Samples processed for macrofossils were etched using a ten-percent solution of glacial acetic acid. A variety of buckets and containers placed inside a well-ventilated fume hood in the acid laboratory were used to hold the samples. Due to highly variable silification of macrofossils, an acetone-based hardener such as Alvar, Butvar or Vinac was used to harden fragile fossils in attempt to increase fossil yield from each block. Alvar or Butvar was preferentially used as they dry clear, whereas Vinac has a yellow tint upon hardening. For this thesis, a mixture of Alvar and acetone was applied by eyedropper or brush to each macrofossil between each successive acetic acid bath.
Insoluble residue from each block was collected and wet-sieved (see below) for conodonts and other microfossils.

Resulting macrofossils were sorted by locality initially according to phylum, where more detailed sorting could be carried out based upon family, genus and species (when possible). Identification of corals, spongiomorphs, and hydrozoans took place at the University of Montana, while bivalves, gastropods, conodonts and chambered sponges were sent out to relevant specialists for proper identification. Specimens were then curated and entered into the paleontology database at the University of Montana, Museum of Paleontology.

Conodont extraction involved techniques in acetic acid dissolution and wet sieving at the University of Montana rock and paleontology preparation labs. I first crushed limestone samples into small pieces one to four centimeters in size using a Braun Chipmunk. One to one-and-a-half kilogram portions of crushed samples were placed into ten-liter plastic buckets. Buckets were then filled with a ten-percent solution of acetic acid and rock samples allowed to dissolve for two days. Then six to seven liters of the acid solution were decanted leaving the remaining sample and a calcium acetate solution. The resulting calcium acetate solution acts as a buffer, maintaining the pH and helping to protect the fragile conodonts. The buckets were then refilled to ten liters with ten-percent acetic acid for further dissolution. The buffered solution reacts slower, so samples remained in the fume hood for three days. Insoluble residues were wet-sieved and washed through a two-sieve stack of 20 (0.841 mm) and 200 (0.075 mm) mesh standard 21cm diameter sieves. Residue in the 20-mesh sieve was collected in a beaker, washed and allowed to air dry. Then placed into a Ziploc bag and stored for future sorting or re-
dissolution. Residue in the 200-mesh sieve was placed in a beaker, washed, allowed to air dry, and sent to Erik Katvala at the University of Calgary for heavy liquid separation (sodium polytungstate solution) and conodont picking using a very fine brush and binocular dissecting microscope.

Photographs of coral and other macrofossils were taken in accordance with Paleotechniques (Grant, 1989) in the paleontology laboratory. Coral samples were blackened with water-soluble, India ink, using a Badger Air-Brush Co., Oilless Diaphragm Compressor, model #180-22. Contrast was then brought out using whitening techniques also described in Paleotechniques (1989). Techniques involved heating granular ammonium chloride in a tempered bulbous glass tube (with holes at both ends) using a Bunsen burner. Rapid heating caused the ammonium chloride to turn directly into gas inside the glass tube. The distal end of the glass tube was connected to an air spigot gently blowing the gaseous ammonium chloride onto the blackened specimen. Care was given to neither over-whiten nor under-whiten specimens. Enhancing techniques were carried out inside a fume hood. Photographs were taken using a Cannon DS6031 EOS 10D digital camera with an optional 65mm macro lens.

(III) Statistical Methods

A data table displaying taxonomic identities of corals according to locality and terrane was created in Microsoft Excel. The statistical program PAleontological STatistics (PAST) by Hammer et al. (2001) was located and downloaded from the Internet to utilize taxonomic coral data for paleobiogeographic analysis. Statistical tests including 1) probabilistic similarity and 2) parsimony analysis of endemicity were carried out to determine paleobiogeographic and paleoecologic relationships. Dr. Paul
Belasky (Department of Earth and Space Sciences, University of California, Los Angeles) provided insight as to specific tests and indices to use while interpreting taxonomic lists.

Methods were used following Belasky et al. (1993, 1994, and 2002) and Yarnell (2000) for running tests (Table 1). Triassic coral data was compiled in list form according to genera and species for Alexander and Wrangellia terrane localities. Data from the Wallowa terrane was utilized from Stanley and Whalen (1989) and data from the Pucará Group (Peru) from Stanley (1994). Coral identification was made from comparisons to published systematic work (see Chapter V Systematic Paleontology). Presence (indicated by a “1”) and absence (indicated by a “0”) data was compiled and placed into adjacent columns within the PAST program. The appropriate test was selected and run from the “Statistics” pull-down menu. The resultant data matrix (RCSI) revealed numerical values of similarity and phylogenetic trees (PAUP) indicated locality or terrane relationships. Taxonomic results were first statistically compared at the locality-level and then at the terrane level based on similarity between terrane localities. Coral taxonomies from the Wallowa terrane and Pucará Group, Peru were also added to establish further similarities.
**Data Input** | **Analysis Type** | **Data Output**
--- | --- | ---
**RCSI** | Binary data matrix using "1" for presence and "0" for absence of taxa | Analysis to test probability that number of species in common will be less than or equal to 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. |
**PAUP** | Binary data matrix using "1" for presence and "0" for absence of taxa | Parsimony analysis of endemcicy (PAE) - phylogenetic analysis using "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. |

**Table 1:** Summary of statistical programs used in this analysis modified from Yarnell, 2001.
Chapter III: Triassic Limestone of the Alexander Terrane

(I) Keku Strait

(A) General History and Age:

The Alexander Terrane encompasses many stratigraphic units throughout much of SE Alaska. Keku Strait and Gravina Island (Figure 4) lie within the recognized borders of the Alexander terrane (Berg, 1973; Muffler, 1967) and were chosen as study areas for abundance of silicified, shallow-water marine fossils within Upper Triassic strata. Keku Strait contains the best preserved and most complete Triassic section within the Alexander terrane. Katvala (2004) extensively studied and described stratigraphic units in the Keku Strait area, paying close attention to the biostratigraphy and lithostratigraphy of the Paleozoic and Triassic units. Therefore, specific geological descriptions of Triassic units have been excluded from this paper.

The Lower Norian (indicated by the presence of the flat clam Halobia and the conodonts Epigondolella quadrata, E. sp. aff. E. spatulata, E. triangularis in Katvala, 2004) Cornwallis Limestone and a limestone unit within the Upper Norian – Rhaetian (indicated by the flat clam, Monotis in Katvala, 2004) Hound Island Volcanics are units within the larger Triassic aged Hyd Group (Muffler, 1967). These units were chosen for study based on abundance of silicified shallow-water marine fossils, specifically corals. Fossils etched from limestone blocks included corals, sponges, spongiomorphs, the globular hydrozoan Heterastridium, brachiopods, crinoid ossicles, echinoid fragments, branching algae, stromatolites, conodonts, fish remains, and occasional bone fragments from marine reptiles as well as a wealth of mollusks including gastropods, large oysters, other sessile and free-living bivalves, nautiloids and ammonoids (Figure 5).
Figure 4 – Map of southeast Alaska showing geographic locations of Keku Strait and Gravina Island. (Modified from Muffler, 1967; Berg, 1973; and Katvala, 2004)
Figure 5 – Partially etched limestone block from MI 0099 showing: A) various silicified fossils following etching in acetic acid, scale bar 10 cm; B) diversity of silicified fauna with jumbled fossils; C) partially etched ammonite and gastropod; D) sphinctozoid sponge Parauvanella sp. identified by Senowbari-Daryan (personal communication, 2005), with annelid worm tubes protruding through matrix; and E) rejuvenated solitary coral, Distichophyllia norica Frech emerging, note immaculately well-preserved ornaments along septal surfaces (arrow). Also illustrated in Chapter V, Plate 1 figures 9, 12, 13 and 14.
(B) Localities:

Many localities have been established within the Cornwallis Limestone by Katvala (2004), from which four main localities are discussed (Table 2): (1) Flounder Cove MI 0099, Montana Invertebrate number (= USGS, M1911), (2) Southwest of Kousk Island MI 0074 (=M2136), (3) Big Spruce Island MI 0056 (=M2135) and (4) Cornwallis Peninsula East MI 0070 (=M1906). Only one relevant locality was established from the Gil Harbor mudflat MI 0087 (=M1912) within the thicker fossiliferous packstone unit of the Hound Island Volcanics. These sites occurred along the Cornwallis Peninsula on Kuiu Island as well as adjacent islands in the Keku Strait area (Figure 6).

(C) Recovered Corals:


A locality along the shores of southwest Kousk Island (SWK) contained large quantities of corals of low diversity. Multiple specimens from the genus *Crassistella* Roniewicz, *Distichophyllia* Cuif and *Gablonzeria* Cuif were recovered from etched limestone blocks. These genera are commonly found world-wide in Upper Triassic
<table>
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<th>Locality</th>
<th>Symbol</th>
<th>Formation</th>
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Table 2: Localities respective to terrane used in this study. Symbols depicted here are used throughout this thesis.
**Figure 6** – Large scale maps of the Cornwallis Peninsula (A) and Eastern Kuiu Island (B) areas. Dots represent Triassic localities visited by Erik Katvala (in 2002 and 03) while Loc numbers are University of Montana Museum of Paleontology locality numbers. Trb = Burnt Island Conglomerate, Trk = Keku Volcanics, Trc = Cornwallis Limestone, Trh = Hamilton Island Limestone, and Trv = Hound Island Volcanics. Figure adapted from Katvala (2004).
strata possibly indicating teleplanic larval dispersion as well as the presence of a highly adaptive species. The colonial cerioid coral, *Crassistella* Roniewicz, is highly variable in growth form, seemingly type-specific to certain localities. Corals from this genus are observed growing as hemispherical mounds, encrusting shells or conglomerate clasts, even growing as large plates suspended in the water column. An encrusting growth form is evident from this locality. Silicification at SWK proved to be rather poor and most colonies are under-silicified as mentioned earlier. Most are preserved as only colony surfaces, in many instances with the obliteration of internal structure. This is the primary reason why encrusting species such as *Crassistella juvavica* Roniewicz were preserved at this locality. Other specimens of *Distichophyllia norica* (Frech) and *Gablonzeria profunda* (Reuss) were preserved but with little significant detail, due in part to coarse-grained silicification, abundant "beekites" and modern intertidal algae. The growth of modern algae on the surfaces of silicified coral is not only difficult to remove; it also seems to destroy much of the delicate detail preserved between adjacent corallites. Specifically corallite walls along colony surfaces that have had algae removed often seem smooth and worn, resembling over-silicification since individual corallite walls cannot be distinguished.

Big Spruce Island (BS) contained silicification almost identical to the SWK locality; however this locality had higher diversity of coral species. This locality presents specimens including *Astraeomorpha* Reuss, *Crassistella* Roniewicz, *Distichomeandra Cuif*, *Kuhnastraea Cuif*, *Pamiroseris* Melnikova and *Thamnasteriomorpha* Melnikova. Corals and spongiomorphs were observed using spongiomorphs, bivalves and other corals as attachment substrate, thus demonstrating ability for vertical growth or tearing.
structure within the water column and of coarse the possibility for reef-like development (UMIP 302895, 302534).

Only two genera of coral (Distichophyllia Cuif and Kuhnastraea Cuif) were recovered from the fourth locality along the east side of Cornwallis Peninsula (CPE). Although this locality recorded the lowest overall diversity in corals from Keku Strait, it contained many varieties of sphinctozoid sponges, large colonies of the calcified sponge Stromatomorpha californica Smith, brachiopods, bivalves and echinoderm spines. Corals were found growing in solitary states within bedded limestone; therefore, no observable structure or reef-like growth was recorded for this particular locality.

Upper Norian to Rhaetian Gil Harbor locality contained lower overall coral diversity in comparison to the Lower Norian Flounder Cove site. Several biofacies were identified based on extreme abundance of gastropods, and bivalves as well as minor occurrences of the spherical hydrozoan Heterastridium and echinoderms (including plates and spines) within limestone beds from this locality (Figure 7). Initial gastropod identification by Blodgett (personal communication, 2005) included a new genus within the subfamily Astraeinae, "Tectus" n. sp. aff. T. interruptum Cox, Planospirina sp., Chulimacula alaskana (Smith), Andangularia wilsoni, Neritopsis (Wallowiella) n. sp., Cryptaulax aff. C. tilarniocnesis Haas, Chartroniella pacifica (Jaworski), Omphalotycha jaworski Haas, Ptychostoma sp., Toxoconcha aff. T. gracilis (Haas) and "Protorecula" sp. Bivalves from the genus Cassianella, Superfamily Pectinacea, and Order Trigonioida have also been preliminarily identified. Coral population is represented by four genera including Astraeomorpha Reuss, Crassistella Roniewicz, Distichophyllia Cuif and Gablonzeria Cuif. Growth is represented by small mound-
Figure 7 – Partially etched limestone block from the Gil Harbor mud flat (MI 0087) showing: A) rich diversity of silicified bivalves (pectinaceous located top of image) somewhat fragmented by original processes, gastropods (new genus from sub family Astraenae above) and annelid worm tubes with random orientation, scale bar 1 cm; B) silicified and fragmented bivalves and spherical hydrozoan Heterastridium.
shaped and plate-like colonies not associated with each other, as well as solitary corals individually found within fine-grained limestone matrix and therefore not exhibiting the kind of structured community that would indicate a reef. Specimens from genus *Crassistella* Roniewicz exhibit both hemispherical mound shapes and encrusting plate-like growth. The encrusting variety of *Crassistella* Roniewicz is illustrated in Figure 8.

In comparison to all other Alexander terrane localities, the preserved fauna from the Gil Harbor mudflat contains the best examples of silicification. Fine-grained silicification helped to preserve minute details such as septal ornamentation including spines in coral specimens, small ribs and growth bands in bivalves and detailed suture patterns in ammonoids. Pyritization and mud-casting also helped to preserve fossils from this locality, but silicification remains the primary mode of preservation.

**(II) Gravina Island**

(A) General History, Age and Lithology:

Another area of study within the Alexander terrane is Gravina Island. Like the Upper Triassic units from Keku Strait, Gravina Island was chosen for study based on known abundance of silicified, shallow water marine fossils originally described by Smith (1927) and later mapped and described by Berg (1973). Stanley (1979) contributed to the tectonic implications of then “suspicious” Alexander terrane, by looking at the reef-building potential and geographic distribution of carbonate buildups from two localities along the west coast, Gravina Island. Montanaro Gallitelli *et al.* (1979) conducted the last major paleontological study of Upper Triassic corals from Gravina Island, by updating the original taxonomy of Smith (1927). The resulting taxonomic list was then used by Yarnell (2001) for paleobiogeographic analysis.
Figure 8 – Silicified coral of genus Crassistella Roniewicz (UMIP 400137) observed encrusting a bivalve from Gil Harbor (MI 0087), Keku Strait.
Upper Triassic stratigraphy from Gravina Island has only been recognized as the Nehenta Formation (Berg, 1973). It has been recognized as being Lower Norian age by an overwhelming presence of the flat clam *Halobia* (Smith, 1915; Chapin, 1918; Martin, 1926; and Berg, 1973) as well as Lower Norian conodonts identified by Katvala (personal communication, 2005). Stanley (1979) assigns this unit to the L. Norian Welleri-Kerri biozone (Figure 9).

The Nehenta Formation has been subdivided into three principal members: (1) a calcareous member that encompasses carbonaceous limestone and siltstone in its lower part and calcareous conglomerate, grit, and sandstone in its upper part, (2) a coarse conglomerate that intertongues with the lower part of the calcareous member, and (3) a basaltic volcanic member occurring in the lower part of the formation (Berg, 1973). Although these three members have been identified, structural complexities have made stratigraphic order within assigned members difficult to determine. Facies variation occurring along the western coast, Gravina Island makes it difficult to distinguish between members one and two.

Following the generalized geological map published by Berg (1973), the Nehenta Limestone is observed cropping out along the intertidal zone on both sides of Gravina Island (Figure 10). A section of the Nehenta Limestone was measured on the east side of the island at Bostwick Inlet (A – A’ on Figure 10) where beds strike almost perpendicular to the beach. The section along this beach (Figure 11) was the only place on the island where the Nehenta Formation could be measured due to perpendicular strike of limestone beds without structural complication.
Figure 10 – General geological map of Gravina Island adapted from Berg (1973) showing the Nehenta Formation (outlined in white). Montana Invertebrate (MI) locality numbers as well as field localities are given, as well as the section measured along the exposure at Bostwick Inlet.
Figure 11 – Measured section of the Nehenta Formation at Bostwick Inlet, Gravina Island (A-A’ on Figure 10). A) Continuation of section up to 680m showing bivalve coquinas, with scattered marine reptile bones at approximately 364m as well as intrusive sills with accompanying metamorphosed shale within the upper part of the section. B) Base of section up to 340m, showing limestone interbeds with *Heterastridium*-rich conglomerate interval at 255m and locations of conodont samples taken.
(B) Biofacies:

Several biofacies were noted within the measured section at Bostwick Inlet as well as exposures along the western side of Gravina Island. Biofacies include: (1) coquinas of densely-packed, shallow-water bivalves and a few gastropods within limestone interbeds cropping out at meter 361 of the measured section, Bostwick Inlet (Figure 12); (2) A Halobia-bearing black calcareous shale/siltstone biofacies surrounds all three members of the Nehenta Formation; (3) a conglomerate interval rich with the spherical hydrozoan Heterastridium crops out at meter 250 of the measured section at Bostwick Inlet (Figure 11A). This unit was recorded also on the west coast, north of Nelson Cove, which may indicate a stratigraphic continuity between both sides of the island; and (4) coral and spongiomorph-rich biofacies are abundant along the west coast of the island, where several different tectonically convoluted depositional environments exist and are described below.

(C) Recovered Fossils:

Lower Norian macrofossils were recovered from both sides of Gravina Island, southeast Alaska. Along the east coast at Bostwick Inlet, recovered fossils include bivalves, gastropods, Heterastridium, algal balls, and scattered, often splintered, bone fragments. Recovered microfossils include conodonts and a few vertebrate bone fragments and fish scales. Majority of macrofossils were non-silicified and mostly replaced by calcite; however, few specimens were preserved with low level-silicification and were etched accordingly. The west side of Gravina Island contained many genera and species of coral (see below), sponges, spongiomorphs, Heterastridium, brachiopods, bivalves, gastropods, echinoderms, crinoid ossicles, large nautiloid and aulacocerid
Figure 12 – Photograph of non-silicified bivalves (trigoniid left and pteriid right) from coquina beds at 364m in measured section at Bostwick Inlet, Gravina Island.
cephalopods, as well as a few bone fragments. Preservation can be described as low-grade, poor or under-silicified for many of the fossils. Within the outcrop, fossils seem well-silicified; however, upon acid etching, minute details are often obliterated, even with the use of a hardener such as Alvar.

(D) Localities:

An incredible lateral variation in facies was recorded along the west side of the island where limestone beds strike in a NE/SW direction, having a general trend approximately parallel to the shoreline. Structural deformation is more intense to the south, along the shores of Nehenta and Phocena Bays (Figure 13A) and less intense along the coastline north of Nelson Cove (Figure 13B). Localities are concentrated in three large areas along the intertidal zone of the western coast: (1) To the south, Nehenta Bay contains two described localities, (2) further north at Phocena Bay, one described locality exists, and (3) the area north of Nelson Cove provides three described fossiliferous localities.

The rocky tidal flats of Nehenta Bay (MI 9930-9932) contain large, out-of-place olistolith limestone reef blocks (up to 7.5m in length), resting in black, highly-fractured and folded calcareous shale matrix (Figure 14A). Olistolith boulders are often weathered from enclosing sedimentary layers, yielding abundant silicified fauna including corals (genera Distichophyllia Cuif, Kuhnastraea Cuif, Crassistella Roniewicz and Thamnasteriomorpha Melnikova), sponges, spongiomorphs, gastropods and brachiopods. Corals and sponges are dominant within these boulders, often growing in situ consistent with reef-like structure inside the blocks (Figure 14B) prior to sliding into deeper water. Nearby beds contain large colonies of encrusting colonial corals
Figure 13 – Field pictures showing: A) intense structural folding of the Nehenta Formation along the tide flat of Nehenta Bay, rock hammer in foreground; B) smaller scale folding of Nehenta Formation North of Nelson Cove, Gravina Island.
Figure 14 – Nehenta Bay (MI 9931) showing: A) olistolith boulder measuring 7.5 meters in length and B) multiserial branching columnar coral colony preserved in life position within olistolith boulder, scale in centimeters.
(Crassistella juvavica Roniewicz and Astraeomorpha crassisepta Reuss) as well as the calcified sponge Stromatomorpha californica Smith. These can also be observed within imbricated limestone clasts as a bedded fossiliferous limestone unit within a volcaniclastic, argillite conglomerate, MI 9930 (Figure 15). This facies interfingers with the Halobia-bearing deeper-water black calcareous shale/siltstone biofacies of this formation.

Further north at Phocena Bay, the Nehenta Formation can be observed cropping out in the intertidal zone of the northern, northeastern, and western shorelines. Only one recrystallized (with calcite), poorly preserved, fossiliferous limestone bed was recognized along the northern shore with abundant halobiid bivalves recovered from the black calcareous shale/siltstone cropping out along the tide line of the bay. The western shoreline, MI 9933 contained abundant, large, complete, but poorly preserved, coral colonies from an interbedded sandy, medium grained limestone unit. All coral colonies seemed to belong to Crassistella Roniewicz; however, only corallite shape is preserved and no septa can be recognized from any of the colonies which exhibit large plate-like growth without evidence of encrusting.

The Nelson Cove area contained an unfossiliferous, massively bedded sandy dolomite unit on the southwest facing arm with black calcareous shale stratigraphically below, covering the inter-tidal portion of the cove. North of Nelson Cove, limestone beds thicken and include at least four different facies exhibiting small-scale structural deformity. The first facies is a fossiliferous limestone with poorly preserved sponges and spongiomorph bioclasts (MI 9936). Coral and spongiomorph colonies are the most abundant organisms within this locality and exhibit either encrusting or plate-like growth.
Figure 15 – Limestone rip-up clasts surrounded by argillite and shale in Nehenta Bay, Gravina Island showing A) slight imbrication of limestone clasts and B) a silicified coral colony of the genus *Crassistella* Roniewicz, scale bar in centimeters.
Colonies are not typically in life position but are visibly broken and often upside down, growing on top of each other. This particular outcrop is interpreted as having a broken-up reef-type ecology or floatstone appearance (Prothero and Schwab, 1999, p. 273).

Calcareous tuff and tuffaceous limestone occur interbedded with a rounded basalt pebble and cobble limestone unit (Figure 16). This unit interfingers with the fossiliferous unit described above. This dominantly volcanic conglomerate facies flanks both sides of the volcanic member that was established formally by Berg (1973). It compares well with the description by Berg (1973), especially with respect to the basalt pillow flows, pillow breccia and subordinate calcareous tuff cropping out of the intertidal zone about 0.25 km north of Nelson Cove.

One mile north of Nelson Cove, the Nehenta Formation consists of medium-fine grained limestone that is massively bedded (4-5 meters thick) and locally may be thrust on top of black calcareous shales. The massive limestone beds contain sporadically concentrated areas of poorly silicified and fragmented colonial corals mostly of the genus Crassistella Roniewicz, as well as few calcareous sponges. Samples were not collected due to poor preservation and massive and inaccessible nature of the outcrop.

Massively bedded, fine-grained, unfossiliferous limestone of this unit grades conformably into a structurally intact fossiliferous limestone reef or biostrome (MI 9935) averaging 8-10 meters thick and 50-58 meters long (Figure 17). Corals are the dominant taxa. They form sinuous, encrusting colonies several meters in length with large plates, up to 0.5 meters long. Thick multiserial columns are interspersed within coralline plates and even mound-shaped phaceloid- and dendroid-growing colonies. Corals are frequently intergrown with several calcified sponges and spongiomorphs, most notably
Figure 16 – A) Volcanic conglomerate facies of the Nehenta Formation with abundant basalt pebbles and cobbles exposed along the surface. B) Surface view of this facies with rounded vesicular basalt cobbles trapped in the matrix, hammer in center for scale.
Figure 17 – Bedded biostrome reef in Nehenta Formation north of Nelson Cove, Gravina Island showing: A) conformable contact with massive limestone below, fallen tree for scale; B) *in situ* structured growth of laminar corals and calcified sponges; C) Surface view of a silicified coral colony with laminar, plate-like growth, colony in center is approximately 20 cm in length.
Stromatomorpha californica Smith and Spongiomorpha ramosa Frech. These framework organisms typically grow on top of one another, forming a reef-like framework structure within this deposit. The coral fauna appears diverse at this locality. Identified coral genera include Kuhnastraea Cuif, Chondrocoenia Roniewicz, Astraemorpha Reuss, Crassistella Roniewicz and Retiophyllia Cuif. The top of the deposit is characterized by a small transgressive sequence of unfossiliferous limestone and shale interbeds grading upwards into black calcareous shale. This unit of the Nehenta Formation cannot be mistaken for an olistolith boulder, primarily because of its bedded nature and conformable contacts stratigraphically above and below the interval, indicating deposition over a continuous time interval.

The presence of a framework reef within the Nehenta Limestone suggests two conditions enabling small-scale reef growth: (1) low rates of sedimentation and a decreased intensity of volcanism in this part of the Alexander terrane and (2) shallow, warm water surrounding the terrane with low nutrient levels and sufficient sunlight for zooxanthellate coral growth (Hallock, 2001).

North of site MI 9935, 1.7 miles north of Nelson Cove, massive fine-grained limestone beds become thinner and less pronounced. Fossiliferous, medium-coarse grained calcareous sandstone and limestone interbeds crop out within black calcareous shale. Interbeds range in thickness from 5-10 cm closer to tide line to 1-2 meters closer to high tide mark, eventually grading into black calcareous shale. Sandstones do not have crossbeds, ripple-marks or any transport indicators. Silicified fossils include bivalves, brachiopods, echinoid spines, gastropods, corals and sponges (MI 9938).
Chapter IV: Triassic Limestone of Wrangellia

Localities from this terrane are separated into two different regions of southeastern Canada and Alaska. These are discussed below.

(I) Northern Wrangellia, south-central Alaska

Another paleontologically important Upper Triassic site is located in the Wrangell Mountains, southcentral Alaska in what is known today as northern Wrangellia. Originally, Mackevett (1965, 1970, 1974, and 1976), Armstrong et al. (1969) as well as Armstrong and Mackevett (1982) extensively mapped and made lithologic, stratigraphic and structural comparisons throughout the Wrangell Mountains. They indicated the presence of a silicified fossiliferous packstone at Green Butte, which they identified as U.S.G.S. M1708. Jones et al. (1977) provided a monumental study concerning tectonic implications of then “suspicious” terranes and consequently their paleogeography. In their study, Jones et al. (1977) provided stratigraphic correlation linking the Wrangell Mountains, Alaska (type section) with Vancouver Island, B.C., Queen Charlotte Islands, B.C., Chichagof Island, Alaska and Wallowa Mountains, Oregon suggesting these five land masses, separated by a distance of up to 2000 km, were part of a much larger terrane coined Wrangellia (Figure 3). Newton (1983, 1983a) revisited M1708 and initiated a systematic study of the bivalves applying her results for paleobiogeographic analysis. She further extrapolated paleoenvironmental conditions as well as paleoecologic interactions between bivalves and gastropod faunas. Montanaro Gallitelli et al. (1979) did not visit this site but studied the U.S.G.S. material provided by N.J. Silberling and provided initial systematic description of the corals. However, the resulting study was not based on a very large sample and subsequent work was needed.
(A) General Stratigraphy and Age:

The Upper Triassic carbonate succession in northern Wrangellia at Green Butte is represented by the Chitistone and Nizina Limestones that overlie a thick Triassic sequence of volcanic rock assigned to the Nikolai Greenstone (Figure 3). The carbonate succession at Green Butte was chosen for study because of the well-preserved, shallow-water silicified fossils concentrated in shell beds within the upper part of the Chitistone Limestone. U.S.G.S. site M1708 was first made known by Silberling (in Armstrong et al., 1969) and the ammonoids *Tropites* cf. *T. welleri* Smith, and *Arcestes* as well as the bivalve *Halobia* cf. *H. superba* Mojsisovics were identified by Silberling (in Armstrong et al. 1969) occurring in a unit 152 meters above the base of the section. These fossils indicated a late Carnian to early Norian age for the Chitistone Limestone.

(B) Lithofacies at Green Butte:

The Triassic limestone at Green Butte is 1,067 meters thick (701 m of Chitistone Limestone and 366 m of Nizina Limestone) as measured above the smooth unaltered surface of the underlying Nikolai Greenstone (Armstrong et al., 1969). The limestone is consistently bedded and shows little evidence of any reef development (Figure 18A). The basal two meters of the Chitistone Limestone were described by Armstrong and Mackevett (1982). It is composed of interbedded, black calcareous shale and pale-yellow, weathered, thinly bedded, argillaceous lime mudstone. A pale-orange to pale-gray medium bedded dolomite makes up the bulk of the unit and is exposed up to 87 meters above the underlying Nikolai Greenstone. Within the Green Butte section, two concentrated fossiliferous deposits were mentioned in Armstrong and Mackevett (1982) but were not described in enough detail to assign a specific bed or location within the
Figure 18 – A) Wrangell Mountain locality MI 9934 (USGS MI1708) along the East face of Green Butte at conformable contact between Chitistone and Nizina Formations. Arrows indicate camp, outcrop as well as other localities where sparse and scattered aulacocerid cephalopods and Halobia were found. B) Locality MI 9934 situated along a steeply inclined talus slope.
section. A pelloid-algae-molluscan packstone is present between 87 and 90 m above the Nikolai Greenstone as well as a massive, gray, algae-molluscan-echinoderm wackstone and packstone at 103.5 m. The latter horizon is believed to be the well-known M1708 designated as University of Montana locality MI 9934 from newly collected material.

(C) Silicified Bed at Green Butte:

This locality is observable cropping out along the eastern edge of a northeast facing talus slope within the large, northeast drainage of Green Butte striking NW/SE at 307° and dipping 32° to the NE, McCarthy B-5 Quadrangle (Figure 18). This deposit is extremely important for its highly diversified shallow-water marine fauna. An early Norian age is indicated by conodonts recovered by Katvala (personal communication, 2005). The fossils are of exceptional quality and preserved by silicification as noted by Newton (1983) and Montanaro Gallitelli et al. (1979). Locality MI 9934 lies close to, if not directly on, the conformable contact between the thick to medium-bedded Chitistone Limestone and the thinly bedded Nizina Limestone. However, recent conodont work by Katvala (personal communication, 2005) reveals a disconformity within the Chitistone Limestone, separating the underlying Late Carnian, thick to medium-bedded limestone and the Early Norian bioclastic, grain supported packstone of MI 9934.

Lithologically, the outcrop consists of a very well-silicified, bioclastic, tabular, grain-supported coquina or packstone (Figure 19A) within a bedded, medium to fine grained limestone matrix, 2.12 m thick and 6.6 m in outcrop length. This grain-supported coquina contains cobble-sized limestone clasts, 2-15 cm in diameter. These clasts are scattered throughout the deposit. No apparent clast imbrication, transport indicators, or preferential orientation of bioclasts are present in the outcrop. However, carbonate clasts
Figure 19 – Locality MI 9934 depicting A) slightly tabular, bioclastic, grain-supported nature; B) intrusion of a silicified high-spired gastropod into limestone clast, scale bar in centimeters; and C) evident scour marking base of the outcrop (dashed black line) with intrusions of fossils into a carbonate clast (arrow).
were soft and unlithified when they were redeposited, as evident by intrusions of fossil lenses into limestone clasts (Figure 19B and C).

Limited lateral extent of the deposit as well as wavy or irregular basal “scoured” contact (Figure 19C) argues for a slope-channel deposit. Furthermore, the grain-supported nature, random and jumbled consistency of bioclasts (lack of preferential orientation), and large trapped clasts of soft carbonate-mud, suggest deposition on the proximal edge of a debris flow (i.e. submarine fan) or the “A” horizon of a turbidite sequence (Howell and Normark, 1998; Prothero and Schwab, 1999, p. 36-41). This slurry-like mass became activated and moved downhill, possibly from local tectonics or gravity on a slope which caused a submarine slide. A species of Halobia was collected and identified as Halobia cf. H. austriaca (Mojsisovics) by McRoberts (personal communication, 2005) from fine-grained limestone directly below the scour (Figure 20). This taxon indicates an earliest Norian (Kerri ammonite biozone) age for the sediments directly below MI 9934 (Figure 9).

(D) Recovered Fossils: 

Well-silicified shallow-water marine organisms including bivalves, gastropods, ammonoids, echinoderms, calcified sponges, spongiomorphs, algae, corals and rare bone fragments were recovered from etched limestone blocks retrieved from MI 9934. Gastropods initially identified by Blodgett (personal communication, 2005) included Amphiscapha sp., Wortheniella spp., Pleurotomaria subcancellata d’Orgigny, Zygites sp., Temnotropis magnus n. sp., three new species from genus Discohelicid, Naticopsis sp., a new genus (and new species) aff. Hyperacanthus, Trypanocochlea n. sp., an undetermined Zygopleurid, Loxonematid with numerous spiral cords, Angularia n. sp.
Figure 20 – Halobiid bivalve *Halobia cf. H. austriaca* (Mojsisovics) found in butterfly position, below scour of MI 9934 (Figure 19), indicating earliest Norian (Kerri ammonite biozone) age, scale bar in centimeters.
aff. *A. subpleurotomaria*, *Spinidelphinulopsis whaleni*, *Paradelphinulopsis valleuri*, *Neritopsis (Wallowiella) vallieri*, *Nuetzelopsis tozeri*, *Eucycloscala* spp., *Chartroniella* n. sp. cf. *pacific* (Jaworski), *Ompahloptycha* n. sp., and *Protorcula* sp. Coral taxa from fourteen genera were identified, including: *Ampakabastraea Alloiteau*, *Astraeomorpha* Reuss, *Chondrocoenia Roniewicz*, *Crassistella Roniewicz*, *Distichophyllia Cuif*, *Gablonzeria Cuif*, *Elysastraea Laube*, *Kuhnastraea Cuif*, *Margarasraea Volz*, *Margarosmilia Volz*, *Pamiroseris Melnikova*, *Pinacophyllum Frech*, *Retiophyllia Cuif*, and *Rhabdophyllia*. Of these fourteen genera, five had previously been described by Montanaro-Gallitelli *et al.* (1979), and ten are new to the locality (Appendix A).

Montanaro Gallitelli *et al.* (1979) also identified species from the genera *Thamnasteriomorpha* Melnikova and *Guembelastraea Cuif* which are not identified in this study.

*Astraeomorpha Reuss*, *Crassistella Roniewicz*, *Kuhnastraea Cuif*, *Gablonzeria Cuif* and *Distichophyllia Cuif* are the most abundant corals within this locality. Colonies commonly exhibit mound-shaped growth and are sporadically intergrown with other corals, spongiomorphs and algae. Such relationships indicate a low level of ecological interaction or competition for growth space. Although the genus *Retiophyllia Cuif* occurs frequently, specimens are highly fragmented and likely came from larger phaceloid-dendroid colonies. By comparison with alpine taxa, corals from this deposit are largely recognized as being Norian; however, the genera *Margarasraea Frech*, *Rhabdophyllia* Laube and *Elysastraea Laube* are indicative of the Carnian from the Tethys.

The fauna at Green Butte presents the best silicification and the greatest diversity of any Upper Triassic locality from the American Cordillera. Upon etching, fossils are
often welded together from silicification and need to be gently separated with a dental pick or other tool. Preservation of fine details such as delicate ornamentation or spines along the lateral surfaces of septa are often observed within some corals, as well as in the shell ornamentation and growth lines of certain gastropods and bivalves. Even echinoid plates and crinoid stems retain their minutely detailed structures.

(II) Southern Wrangellia

(A) General Stratigraphy and Age:

Jones et al. (1977) documented sites on Vancouver Island which represent a southern fragment of Wrangellia, correlated with Triassic rocks from the Wrangell Mountains (Figure 3). Triassic rocks of Vancouver Island are comprised of three formations that have been extensively studied by many geologists (Fyles, 1955; Muller et al., 1974; Massey and Friday, 1987; Yorath et al., 1999). Stratigraphically, from oldest to youngest, these are the Karmutsen, Quatsino, and Parson Bay Formations that together make up the larger Vancouver Group. The underlying Karmutsen Formation is largely volcanic, correlating stratigraphically, lithologically and chemically with the Nikolai Greenstone of the Wrangell Mountains in south-central Alaska but differing with respect to percentage of pillow basalts and aquagene tuffs (Jones et al., 1977). As in the Triassic rocks from the Wrangell Mountains, the overlying Triassic units from Vancouver Island are composed of carbonate rocks.

The Quatsino Formation is a light gray, massive to thickly bedded or blocky to flaggy dark gray limestone, interbedded with shale and recognized as a shallow-water platform carbonate (Jeletzky, 1970; Muller et al., 1974; Carlisle and Susuki, 1974; Yorath et al., 1999). This formation correlates stratigraphically with the Upper
Carnian/Lower Norian Chitistone Limestone in south-central Alaska (Jones et al., 1977; Yorath et al., 1999). Carlisle and Susuki (1974, pp. 258-263) have recognized a late Carnian conformable contact between the Quatsino Formation and the overlying Parson Bay Formation based on exposures occurring at many sites on Vancouver Island. The entire extent of the Parson Bay Formation and associated stratigraphic relationship with the Sutton Formation has been subject to different interpretations. Muller (1977), Jones et al. (1977), as well as Massey and Friday (1987) placed the Sutton Limestone as a member within the Parson Bay Formation; however, Clapp (1912) and Yorath et al. (1999) recognized the Sutton Limestone as an individual formation overlying the Parson Bay Formation largely due to its distinctive character and widespread distribution. This paper follows the stratigraphy set forth by Muller (1977), Jones et al. (1977), and Massey and Friday (1987) designating the Sutton Limestone as a member within the Parson Bay Formation.

(B) History of the Parson Bay Formation:

Bancroft (1913) established the Parson Bay Group for exposed outcrops of shale, limestone, and minor volcanic rocks located along Parson Bay on Harbledown Island, north of Vancouver Island. However, upon recognition of both Jurassic and Triassic fossils within the group, Crickmay (1928) subdivided the Parson Bay Group into two formations: (1) the Parson Bay Formation includes Triassic rocks and (2) the Harbledown Formation includes Jurassic rocks. Yorath et al. (1999) stratigraphically correlated the Parson Bay Formation of Vancouver Island with the Nizina Limestone and McCarthy Formation of south-central Alaska.

(C) General Lithology and Locality:
The Parson Bay Formation has a highly variable lithology, containing thinly bedded shale, limestone, argillite, sandstone, minor volcanic rocks as well as many benthic and pelagic shallow-water marine fossils (largely within the Sutton Member). Fossils include corals, bivalves, gastropods and ammonoids (Fyles, 1955; Jones et al., 1977; Massey and Friday, 1987; Stanley, 1979, 1989). These fossils have been interpreted by Carlisle and Susuki (1974) as Upper Norian – Rhaetian based on the presence of the flat clam *Monotis subcircularis*.

The Parson Bay Formation has been observed cropping out at various localities throughout Vancouver Island. For this work, three localities were selected for study: (1) the southern shore of Lake Cowichan, (2) Tahsis Inlet on the west coast and (3) Quatsino Sound to the north (Figure 21). At Tahsis Inlet, fossiliferous localities were identified and sampled (unpublished data) by M. Orchard and D. Erwin as well as Stanley and K. Paisley. Field notes from Stanley and Paisley indicate that samples were collected from four sites.

Stanley and Paisley (personal communication, 2005) note site 1 as steeply dipping bedded limestone, volcanics, calcareous mudstone and argillite cropping out along a reclaimed logging road near Lutes Creek in an unnamed valley located west of Tahsis Inlet near the town of Tahsis (Figure 22A). Here limestone is leached with molds of corals, trigoniid bivalves, gastropods, brachiopods, echinoids, and crinoid ossicles. Corals, also preserved as molds, were both solitary and colonial. Site 2, approximately 1 km from site 1, is located in a small ditch within the valley. Abundant fossil molds of stromatoporoid-like organisms as well as trace fossils and possible molds of crab claws
Figure 21 – Satellite image of Vancouver Island showing the location of the three study areas used in this thesis. (Modified from www.googlemaps.com).
Figure 22 – A) Coral horizon of Parsons Bay Formation at Tahsis Inlet, Vancouver Island (MI 9913). B) Fossil mold of the meandroid coral *Margarastreaa klipein* Frech from MI 9913, rock hammer for scale.
were collected. Site 3 (MI 9913) is stratigraphically below site 2 and contains molds of phaceloid and meandroid corals (Figure 22B) as well as thick trigoniid bivalves within bedded limestone. Site 4 is located in the Quatsino Formation along the eastern shoreline of Tahsis Inlet. It contains molds of corals from the genera *Distichophyllia* Cuif, *Margarastraea* Frech and *Distichomeandra* Cuif, as well as sponges, bivalves, brachiopods and the calcified sponge *Stromatomorpha californica* Smith.

(D) History of the Sutton Member:

Clapp first recognized the Sutton Member as an individual formation which included all of the intercalated limestones within the Vancouver Group of southern Vancouver Island (Clapp and Shimer, 1911). Silicified shallow-water marine fossils collected from the type section at Lake Cowichan were mistakenly identified as early Jurassic by Clapp and Shimer (1911); however, subsequent work by Fyles (1955) and Shimer (1926) showed them to be Late Triassic in age. Likewise, detailed mapping and stratigraphic revision have placed this limestone as a member within the Parson Bay Formation (Muller, 1977; Massey and Friday, 1987).

The bulk of the Sutton Member occurs along the southwest flank of the Cowichan Anticlinorium, cropping out at three main localities: (1) Clapp and Shimer (1911) identified the type section along the south shore of Lake Cowichan (MI 8302), Vancouver Island, about 4.8 km west of Sutton Creek (Figure 23); (2) a section 60 m thick at Redbed Creek, identified in Yorath *et al.* (1999) as well as the adjacent creek to the north and (3) a locality near Sproat Lake also identified in Yorath *et al.* (1999). The Sutton Limestone lies unconformably on top of the Karmutsen Formation, along the Cowichan Anticlinorium and contains abundant coarse-grained cobbles and breccia of
Figure 23 – Satellite image of Lake Cowichan, southern Vancouver Island showing location of the Sutton Member outlined in white. (Image from www.googlemaps.com. Geology adapted from Massey and Friday, 1987)
Karmutsen Formation origin which are trapped within its limestone matrix (Yorath et al. 1999). Fyles (1955) noted that the Sutton Formation at Lake Cowichan grades laterally into basalt flows and volcanioclastic rock which Stanley (1989) asserted, had been correlated mistakenly with the Karmutsen Formation along subtle fault contacts.

(E) Biofacies:

Clapp and Shimer (1912) as well as Stanley (1979, 1989) noted the existence of at least three distinct zones or biofacies within the thin – medium bedded, fine-grained gray fossiliferous and flaggy limestone striking approximately parallel to the beach of Lake Cowichan MI 8302 (Figure 24). These include (1) a diverse coarse grain-supported, bivalve packstone in a fine-grained limestone matrix which includes bivalves, gastropods, echinoderms, cephalopods and worm tubes (Figure 25A); (2) an in situ branching coral zone of moderate diversity represented by the genus *Retiophyllia* Cuif (Figure 25B); and (3) an encrusting flat coral zone dominated by genera *Anthostylis* Roniewicz, *Margarastrea* Frech, *Astraeomorpha* Reuss *Kuhnastraea* Cuif *Crassistella* Roniewicz and *Gablonzeria* Cuif (Figure 25C).

Stanley (1979, 1989) reported on gross paleoecology and biofacies at Lake Cowichan, compiling a species and faunal list for recovered fossils in a measured section 71.7 m thick. Collected limestone blocks from this site were used for acid etching, and well-preserved material was retrieved. This site is designated MI 8302.

Fine silicification has preserved significant amounts of detail and diversity within shallow-water marine fauna at Lake Cowichan. Silicification and texture of biofacies resemble that of Green Butte (MI 9934), where minute details are preserved, as well as similar cementation of fossils within the bivalve-packstone biofacies (1) as described
Figure 24 – Medium bedded, fine-grained limestone beds of MI 8302 (dipping 45°, striking NE/SW) along the southern shores of Lake Cowichan, Vancouver Island, sledge hammer center-left for scale.
Figure 25 – Biofacies of MI 8302 showing: A) packstone biofacies with silicified bivalves, gastropods, echinoids and corals; B) *in situ* branching coral biofacies evident by the phaceloid coral *Retiophyllia clathrata* Emmrich, sledge hammer head bottom-right for scale; C) encrusting coral biofacies showing a fragmented colony genus *Crassistella* Roniewicz, scale bar in centimeters.
above. Some earlier collected material was etched in HCl, but subsequent collected material was processed with acetic acid which yielded better results (Figure 26).

Unpublished data from Stanley and Fois-Erickson reveal another locality within the Sutton Member at Quatsino Sound in northern Vancouver Island (MI 9947). Lithologically, locality MI 9947 is a fossiliferous dark gray, medium – fine-grained relatively pure limestone with chert stringers. The locality is observed cropping out near a rockslide at Pender Point in Quatsino Sound, northern Vancouver Island. *Retiophyllia* Cuif was identified in the field and the genera *Astraeomorpha* Reuss and *Gablomzeria* Cuif were identified from etched samples. Silicification of corals from Pender Point is not as complete (under-silicified) as in samples from the type locality at Lake Cowichan (MI 8302). Within this coral population, most of the external features including epitheca and colony shape are preserved by fine-grained silicification; however, silicification does not penetrate the entire colony. This is especially evident in samples of the genus *Retiophyllia* Cuif, making specimens extremely fragile and easily fragmented after etching.
Figure 26 – Specimens from Lake Cowichan, MI 8302: A) Anthostylis cf. A. acanthophora (Frech) processed in HCl with corallites possessing little or no structural detail and B) Chondrocoenia schaafhaeuli (Winkler) etched in acetic acid; retaining much corallite detail throughout the colony, scale bar 1 cm. Specimen also illustrated in Ch. V, Pl. 4, figures 3, 7 of this thesis.
Chapter V Systematic Paleontology

All specimens are curated in the University of Montana paleontological collections. Type material from previous collections made by Clapp and Shimer (1911) and Smith (1927) were kindly sent from the National Museum of Natural History, Smithsonian Institute. The following Late Triassic Coral systematic identifications have been made based on a foundation set forth by European Alpine reef faunal work of Reuss (1854) Laube (1865) Frech (1890) and Volz (1896) adhering to the revolutionary modern classification scheme set forth by Cuif (1966 – 1976) and Roniewicz (1989).

Data in tables of this chapter concerning quantitative properties of coral taxa follow Roniewicz (1989):

UMIP – University of Montana Invertebrate Paleontology catalogue number.

Colony – Colony dimensions (in mm) for individual specimens. Note, multiple specimens may have one UMIP number.

\( d \) – Corresponds to the corallite diameter (in mm) for individual corallites within a single colony.

\( s \) – Relates to the number of counted septa within a given corallite.

\( s / 3 \text{mm} \) – Relates to the number of septa occurring in three millimeters of a calice, usually used in cases with meandroid corals, or in cases where there are many fine septa warranting an average instead of a direct count.

\( s / 5 \text{mm} \) – Corresponds to the number of septa present in 5 millimeters.
Remarks – This column is reserved for direct comments about the individually measured colony (i.e. state of preservation or stage of life (juvenile or adult)) that may help give insight to a certain measurement.

Class ANTHOZOA

Order SCLERACTINIA Bourne, 1900

Suborder PACHYTHECALIINA Eliášová, 1976

Superfamily VOLZEIOIDEA Cuif, 1977

Family CYCLOPHYLLIIDAE Roniewicz, 1989

Genus KOMPSASTERIA Roniewicz, 1989

_Type Species._ – _Isastraea oligocystis_ Frech, 1890

**KOMPSASTERIA OLIGOCYSTIS (Frech, 1890)**

(Plate 1, Figures 1, 2)

_Isastraea oligocystis_ FRECH, 1890, p. 24. Pl. 5, figs. 8, 8A, 8b, 8B

_Kompsasteria oligocystis_ (Frech) RONIEWICZ, 1989, p. 30, Pl. 2, figs. 2,3, Pl. 3, figs. 1-5

_Material._ – A single silicified colony from the Cornwallis Limestone Keku Strait MI 0099 (M1911), southeast Alaska.
### Dimensions (in mm)

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**Description.** — Colony lamellate, cerioid integration. Corallite walls broad without significant detail. Walls surround shallow, relatively well preserved subcircular to slightly polygonal calices. Two to three orders of septa extend toward central axis but do not fuse to form columella. Granular silicification destroyed much septal detail. S1 synapticular wedge-shaped, extending between ¼ and all the way to calical center. S2 thinner, extend up to ½ length of S1 septa. S3 rare, visible only as small projections along corallite wall.
Discussion. – Roniewicz (1989) identifies this distinctive genus primarily by septal microstructure and gross corallite and colony morphology. A detailed description is also given by Roniewicz (1989), pertaining primarily to septal microstructure. Our specimen does not present any septal microstructure, but matches well with specimens presented by Roniewicz (1989) in corallite dimensions (including diameter) and colony morphology. The lack of significant details in corallite walls may be attributed to weathering, water (abrasion by surrounding sediment) or by poor preservation.

Occurrence. – Norian, Keku Strait, SE Alaska; Rhaetian, northern calcareous Alps (Zlambach Beds of Schneekengraben and Kesselwand-Rohrmoos). This is the first report of this taxon outside of the western Tethys realm.

Family GABLONZERIIDAE Roniewicz, 1989
Genus GABLONZERIA Cuif, 1976

Type Species. – Isastraea profunda major Frech, 1890

GABLONZERIA MAJOR (Frech, 1890)

(Plate 1, Figures 3, 8)

Isastraea profunda (Reuss) var. major FRECH, 1890, p. 22, Pl. 5, figs. 4, 5

Isastrea whiteavesi CLAPP AND SHIMER, 1911, Pl. 40, fig. 9

Elysastrea major (Frech) SQUIRES, 1956, p. 26, figs. 52, 53

Isastraea profunda major (Frech) CUIF, 1976, p. 114, text-fig. 13, Pl. 11, fig. 1, Pl. 12, figs. 4, 5
*Gablonzeria major* (Frech) MATZNER, 1986, Pl. 9, fig. 8; RONIEWICZ, 1989, Pl. 4, figs. 2, 3, 4, Pl. 5, figs. 1, 2

**Material.** – Five specimens from northern Vancouver Island Canada at Pender Point (MI 9947) and one specimen found by Clapp and Shimer from the Upper Triassic limestone at Lake Cowichan southern Vancouver Island, Canada.

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**Description.** – Laminar to mound shaped colonies. Corallites well preserved, hexagonal to pentagonal with sharp distinct walls, no columella, deep calical depressions and little variation in diameter between adult individuals. Three cycles of septa moderately to well preserved with no details. S1, S2 extend to ½ corallite radius with equal thicknesses. S3 are thinner, wedge-shaped, extend ¼ length of radius and taper vertically toward each calical depression.

**Discussion.** – Roniewicz (1989) bases the description of this species on its morphology and microstructure. Our specimens match well morphologically with the original illustration by Frech (1890) and have similar corallite size, shape, and septal arrangement to the description and illustrations given by Roniewicz (1989).
Occurrence. – Rhaetian from Vancouver Island, Canada (at Pender Point and Lake Cowichan); northern Calcareous Alps (Zlambach Beds of the Gosauklamm region and in Fischerwiese); Lewiston, Idaho.

**GABLONZERIA PROFUNDA (Reuss, 1854)**

(Plate 1, Figures 4, 5)

*Isastraea profunda* REUSS, 1854, p. 116, Pl. 9, figs. 5, 6; FRECH, 1890, p. 21, Pl. 5, figs. 1-3A; 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.* KANMER, 1964, p. 129, Pl. 13, fig. 11.


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

*Actinastraea (?)* sp. MONTANARO GALLITELLI et al., 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. – Eight silicified specimens from the Cornwallis Limestone in Keku Strait, MI 0099 (M1911) and MI 0074 (M2136). Fifteen silicified specimens from the Chitistone Limestone MI 9934 (M1708).

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Description. – Colony mound-shaped, cerioid. Corallites oval or circular with shared walls, intracalicular budding and variable corallite diameters. Calical depressions slope toward calical center. Three orders of septa extend to central axis but do not fuse to form
columella. S1 thicker, wedge-shaped, being straight or wavy, protruding $\frac{1}{2}$ way to central axis. S2 thinner, extend $\frac{1}{4}$ way to axis. S3 exist as small projections along wall.

Discussion. – Cuif (1976) redefined the genus Gablonzeria Cuif based on microstructure present in nonsilicified specimens. Specimens used in this study range in silicification and therefore do not present any visible microstructure. However, our specimens were assigned based on gross morphology previously established by Reuss (1854) and also used by Stanley and Whalen (1989).

This genus and species has a complex history. Although sometimes misidentified, *G. profunda* has been assigned to many different genera over time. Smith (1927) illustrates *Isastraea profunda* (Pl. 114, fig. 2) from many different localities within the North American cordillera. Montanaro Gallitelli et al. (1979) indicate a close resemblance to *Cyathocoenia* aff. *Carinata* Cuif, as well as an illustration of a coral from Hells Canyon, Wallowa Mountains, as *Actinastraea* (?) sp. (Pl. 1, fig. 2a, b) to which Stanley and Whalen (1989) note a resemblance to *G. profunda* (Reuss 1854).

This species is extremely widespread. It has been reported from different localities within the many terranes of the Canadian and North American Cordillera as well as areas including Austria, Siberia and Japan. Stratigraphically, it has been reported from Lower Norian – Rhaetian strata. Due to its wide spread occurrences, this particular coral was most likely a dominant, opportunistic species that had teleplanic larvae dispersing over large distances, adapting, to many different ecological conditions.
Occurrence. – Vancouver Island (Lake Cowichan), Lime Peak (Yukon) Canada; Keku Strait, Wrangell Mountains, Lake Iliamna, Alaska; Hells Canyon, Wallowa Mountains, Oregon; Lewiston (Mission Creek), Idaho; Pilot Mts., Nevada; Lake Shasta, California, Lime Peak (Yukon), Canada; Zlambach beds, Austria; Pamir Mountains, Russia; Japan and northern Chile.

GABLONZERIA SP. A

(Plate 1, Figures 6, 7, 10, 11)

Diagnosis. – Massive colony, cerioid. Corallite walls polygonal, sharp, with deep calices and no columella. Intracalicular budding occurs by fusing septa. Three to four orders of septa present. S1 reach central axis, strait, wavy or zigzag shaped.

Material. – One single nonsilicified colony found as float within the Nehenta Limestone MI 9930 on Gravina Island, SE Alaska.

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Description. – Massive cerioid colony. Corallite walls polygonal, sharp, with deep calices and no columella. Three to four orders of septa present. S1 reaches central axis,
wedge-shaped, thicker towards endotheca, strait, wavy or zigzag shaped. S2 thinner, reach $\frac{1}{2}$ the length of S1 septa. S3 extend $\frac{1}{4}$ length of S1. S4 rare, visible as small projections along endotheca. Dissepiments occur between S1 and S2 septa and rarely between S3 and S4. Intracalicular budding occurs by fusing S1 septa across parent corallite; similar to cell division (Pl. 1, fig. 11).

**Discussion.** – Our material strongly resembles illustrations of *G. profunda* (Reuss) and *G. major* (Frech) in Roniewicz (1989 Pl. 4, figs. 1a, 2a-b) with respect to growth form, septal arrangement and overall look. However, this species has corallite diameters that are twice the size of *G. major* (Frech).

This coral is placed into *Gablonzeria* Cuif, having similar morphological characteristics such as corallite shape, septal attributes and mode of budding. Most notably the septa, differentiated into 3 orders S1 being the thickest, typically reaching the central axis and having a strait or zigzag appearance which match well with the genus description by Roniewicz (1989).

UMIP 400488 is a fragment of a non-silicified colony and therefore does not have a clearly defined shape. However, given the size of the colony (19.5 cm) and the massive nature of its growth; it can be hypothesized that this species is mound or plate-like.

**Occurrence.** – Lower Norian from Gravina Island, SE Alaska.

Suborder CARYOPHYLLIINA Vaughan and Wells, 1943
Superfamily REIMANIPHYLLOIDEA Melnikova, 1975
Family DISTICHOPHYLLIIDAE Cuif, 1977

Genus DISTICHOPHYLLIA Cuif, 1975a

Type species. – Montlivaltia norica Frech 1890

DISTICHOPHYLLIA NORICA (Frech, 1890)

(Plate 1, Figures 9, 12-14)

Montlivaltia cupuloformis 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 gossaviensis 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, fig. 2; STANLEY, 1979, Pl. 2, figs. 8-10; KRISTANTOLLMANN, 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.

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

Montlivaltia norica Frech. SCHÄFER, p. 44, Pl. 10, fig. 1, Pl. 11, 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; RONIEWIČZ,
1989, p. 39, Pl. 6, figs. 2-4; STANLEY, 1994b, p. 88, Pl. 4, figs. 3,4.

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

**Material.** – Fifteen silicified corals from the Cornwallis Limestone MI 0099 (M1911), MI 0087 (M1912), MI 0074 (M2136), MI 0070) Keku Strait in southeast Alaska. Twenty-seven silicified corals from the Chitistone Limestone MI 9934 (M1708) in the Wrangell Mountains, southcentral Alaska.

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**Description.** – Solitary coral, variable height, conical or cylindrical shape. Corallites rejuvenate intercalicularly, forming large multi-generational stalks extending into water column. Thin to moderately thick epitheca present. Septa meet at calical center or form axial fissure. S1 and S2 thickest, uniform more pronounced, extend to center, with
ornamentation or spines along lateral surfaces parallel to central axis (Pl. 1, figs. 12, 14).
Silicification destroys much detail along septal surfaces. S3 extend \( \frac{1}{2} - \frac{3}{4} \) to center. S4 (if present) thinnest extending \( \frac{1}{4} - \frac{1}{2} \) radius.

Discussion. – Our specimens match well with illustrations given by Squires (1956), Montanaro Gallitelli et al. (1979), and Stanley and Whalen (1989). Roniewicz (1989) gives terrific details of septal orders and species characteristics that compare well with our specimens. We observe only 3-4 orders of septa in comparison to 5 orders described by Roniewicz (1989) due to silicification. Zankl (1969) added to coral morphology by reporting lateral budding, resembling a pseudocolonial integration. However, none of our specimens exhibit this form of reproduction. Frech (1890) also illustrates specimens with a twisting or sunken axial fissure (Pl. X fig. 1-5) to which none of our specimens match.

This species is extremely common and widespread. It occurs from Lower Norian – Rhaetian time, and is found from many localities in the North American and Canadian cordillera as well as localities in Asia, Europe and Japan. Due to the geographical extent of this coral, it can be concluded that *D. norica* was an opportunistic coral or larval dispersalist (i.e. broadcaster in reproductive strategy), capable of adapting to a wide variety of ecological conditions in order to maintain populations throughout the Upper Triassic.

Occurrence. – Wrangell Mountains, Keku Strait, Long Creek, Alaska; Vancouver Island (Lake Cowichan), Canada; Hells Canyon, Wallowa Mountains, Oregon; Lewiston (Mission Creek), Idaho; Pilot Mountains, Nevada; Dachstein Reef limestone and
Zlambach beds, Austria; Mt. Everest, Tibet; Timor; Southeastern Pamir Mountains and Koryak Highlands, northeastern Russia; Japan.

“MONTLIVALVIA” cf. “M.” MARMOREA Frech, 1890

(Plate 1, Figure 17)

Montlivaltia marmorea Frech, 1890, p. 41, Pl. 11, figs. 6, 6A

Material. – A single nonsilicified individual from the Nehenta Limestone Gravina Island MI 9930, southeast Alaska.

<table>
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</table>

Description. – Poorly preserved disk-shaped colony, solitary, surrounded and partially covered by a quartz pebble conglomerate, central portion heavily re-crystallized. Septa best preserved around corallite wall, trending toward calical center. Four to five orders of septa preserved. S1 thickest, extending to central axis. S2-S5 of equal thickness, obscured by re-crystallization.

Discussion. – Frech (1890) illustrates Montlivaltia marmorea to be a solitary coral clearly resembling D. norica, but differs by having more numerous septa (approximately 240), a larger diameter, and numerous dissepiments between septa. Roniewicz (1989) describes D. norica with an average diameter of 12-50mm and 65-186 septa. Our specimen clearly has a much larger calical diameter and septal count to D. norica described by Roniewicz.
(1989). From these differences, in conjunction with similarities to Frech’s (1890) specimen, we conclude our specimen to tentatively be “M. ” marmorea Frech.

We further include “M.” marmorea Frech into the genus Distichophyllia Cuif primarily because Roniewicz (1989) mentions the genus Distichophyllia Cuif was derived from an older genus Montlivaltia (which is no longer valid in the Triassic). She maintains that Distichophyllia includes D. norica (Frech, 1890) and D. fritschi (Frech, 1890) and possibly other species that have not yet been studied with great detail; such as “Montlivaltia” marmorea Frech.

Occurrence. – Lower Norian, Gravina Island, southeast Alaska; Norian, from localities in Europe.

Genus RETIOPHYLLIA Cuif, 1967

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

RETIOPHYLLIA ALFURICA (Wilckens, 1937)

(Plate 2, Figures 24, 27, 28, 31)

Thecosmilia alfurica Wilckens, 1937, Pl. 9, Figure 1, 2

Material. – Four silicified colonies and many fragments from northern Vancouver Island, Canada (MI 9947).
Dimensions (in mm)

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<td>8.0x6.5</td>
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</table>

Description. – Low growing, dendroid, colonial coral with thin or non-existent epitheca. Corallites bifurcate in pairs of equal thickness and length. Circular calices trumpet shaped, taper toward stalk. Septa moderately well preserved, granular silicification produces pseudo ornamentation along lateral surfaces of S1 septa (Plate 2, Figure 31). Three to four orders of septa of different thicknesses preserved. S1 most prominent, extending half the calical radius. S2 thinner only ½ length of S1. S3 hard to distinguish from endotheca, only observed as small projections. S4 rare, hard to distinguish from S3.

Discussion. – Wilckens (1937) originally described and illustrated this species from Seran. It is apparent from the publication that the holotype was not etched in acid and therefore the specimen has little in the way of colony growth form. However, the illustration shows the characteristic trumpet shape to calices, paired budding within the colony, as well as similar corallite dimensions that are synonymous with our specimen.
Our material also contains phaceloid or dendroid integration, budding intratentacularly with symmetrical bifurcation (and occasionally trifurcation) of corallites. These are all common characteristics within the genus *Retiophyllia* Cuif. Because of these similarities we place the species *alfurica* into the genus *Retiophyllia* Cuif, most notably because the genus *Thecosmilia* is no longer valid within the Triassic (Cuif, 1967). Furthermore, through personal communication with Dr. Roniewicz, a re-examination of the holotype material within the publication by Wilckens (1937) has tentatively placed this species into the genus *Retiophyllia* Cuif as well.

**Occurrence.** – Upper Triassic from northern Vancouver Island, Canada; and Seran.

**RETIOPHYLLIA CAESPITOSA (Reuss, 1865)**

(Plate 2, Figures 1, 2, 5, 6)

*Thecosmilia caespitosa* REUSS, 1865, p. 159, Pl. 3, fig. 3; FRECH, 1890, p. 7, Pl. 1, figs. 1-12, (not fig. 13); CUIF, 1966, p. 534, text-fig. 2B

*Thecosmilia caespitosa* (Reuss, 1865) n.v. *pauciseptata* HAAS, 1909, p. 144, Pl. 5, fig. 1

*Distichophyllum caespitosum* (Reuss), CUIF, 1967, p. 129, text-fig. 3, Pl. 4, fig. 3; CUIF, 1975, p. 375, text-figs. 35b and 36; MELNIKOVA, 1986, p. 47, Pl. 13, fig. 2

*Retiophyllia caespitosa* (Reuss, 1865), RONIEWICZ, 1989, Pl. 8, figs. 2, 4, 9, Pl. 9, fig. 3

*Material.* – Thirty-five silicified colonies from the Chitistone Limestone Mi 9934 (M1708) in the Wrangell Mountains, southcentral Alaska.
Dimensions (in mm)

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</table>

Description. – Phaceloid, frequently bifurcating, individually or in groups (up to three). Corallites circular or oval, taper towards stalk. Thinly folded (rugae) epitheca surrounds colony, thickest around calical rim. Calical depression tapers (8mm deep), septa do not reach calical center, no columella. Three to four orders of septa preserved, wedge shaped. S1 and S2 of equal thickness, S1 extends ¾ radius, contain ornamentation (Pl. 2, fig 6). S2 ½ length of S1. S3 and S4 exist only along endotheca.

Discussion. – Our specimens match the detailed morphological description given by Roniewicz (1989). *R. caespitosa* is distinctive in its frequent bifurcation, proportionate thickness of all radial elements, club or wedge-shaped internal edges of septa within specimens with a thickened skeleton and S1 septa that do not extend the entire radius leaving a free cavity at the center of corallites.

Stanley (1986, p. 27: a list of verified taxa) lists *R. caespitosa* as occurring in Hells Canyon, Oregon; however, this species is not illustrated in the comparative taxonomy of Stanley and Whalen (1989) and therefore no comparison could be made.
between North American specimens of *R. caespitosa*. The occurrence of *R. caespitosa* in Hells Canyon would be vital in comparing coral faunas of the Wallowa terrane, Oregon with northern Wrangellia, southcentral Alaska. Smith (1927) describes a specimen identified as *Thecosmilia cf. T. caespitosa* Reuss from Iliamna Lake, Alaska (Pl. 121, fig. 7); however, illustrations do not show any distinguishing characteristics with those from Reuss (1865) or Roniewicz (1989) and therefore cannot be counted as a valid North American occurrence.

*Occurrence.* – Lower Norian Wrangell Mountains, southcentral Alaska; Norian from the Caucasus, central and northeast Asia; Rhaetian of the northern Calcareous Alps (Zlambach Beds from Fischerwiese and Zlambachgraben).

**RETIOPHYLLIA CLATHRATA (Emmrich, 1853)**

(Plate 2, Figures 3, 4, 11, 12)

*Thecosmilia clathrata* Emmrich FRECH, 1890, (part) Pl. 4, fig. 11

*Thecosmilia fenestrata* Reuss FRECH, 1890, (part) Pl. 2, figs. 11 and 12a, b

*Calamophyllia suttonensis* CLAPP & SHIMER, 1911, p. 431, Pl. 40, fig. 5, 7, Pl. 42, fig. 15

*Thecosmilia fenestrata* SMITH (not Reuss), 1927, p. 128, Pl. 105, fig. 1, 9

*Thecosmilia cf. suttonensis* (Clapp & Shimer) SQUIRES, 1956, p. 22, fig. 31

*Thecosmilia Wrangelliana* RUSSO in Montanaro Gallitelli et al., 1979, Pl. 4, fig. 3

*Retiophyllia dawsoni* (Clapp and Shimer, 1911) STANLEY AND WHALEN, 1989, figs. 5.8, 5.9, 5.13, 5.14
*Retiophyllia clathrata* (Emmrich) PRINZ, 1991, p. 156, Pl. 1, fig. 4

**Material.** – Four large silicified colonies from Lake Cowichan southern Vancouver Island, Canada MI 8302. Twenty fragmented and silicified colonies from the Chitistone Limestone MI 9934 Wrangell Mountains, southcentral Alaska.

<table>
<thead>
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<th>Dimensions (in mm)</th>
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</table>

**Description.** – Phaceloid, acutely branching colony. Calice bifurcates into two parallel equal-dimensional long stalks, occasionally bulbous in shape, supported by frequent hollow connecting processes situated sporadically along vesicular epitheca (Pl. 2, fig. 11). Circular / oval calices support four orders of septa. Dissepiments frequently occur between all four orders of septa. S1 and S2 most prominent, equal length, extend to central axis, S1 thickest. S3 very thin, \( \frac{1}{2} \) length of S1. S4 rarely observed, \( \frac{1}{4} \) length of S1.
Discussion. – From this study, we have concluded that corals in synonymy with *Calamophyllia suttonensis* Clapp and Shimer have identical characteristics as *R. clathrata* (Emmrich) with regard to parallel branching, equal bifurcation, and frequent connecting processes for colony stabilization and potential communication between adjacent corallites. For these reasons, we place *Calamophyllia suttonensis* Clapp and Shimer in synonymy with *R. clathrata* (Emmrich).

Stanley 1989, notes *R. clathrata* (Emmrich) collected at Lake Cowichan, grew just off shore in the subtidal zone within the fair weather wave base. *R. clathrata* (Emmrich) could have been a potential reef builder during Upper Triassic time, due to the dense, vertical growth and substantial colony size.

Occurrence. – Rhaetian from Vancouver Island, Canada; Lewiston, Idaho; Lower Norian from Wrangell Mountains, Iliamna Lake, Cook Inlet, Alaska; Hells Canyon, Oregon; northern Chile; Europe.

**RETIOPHYLLIA DAWSONI** (Clapp and Shimer, 1911)

(Plate 2, Figures 16-18)

*Calamophyllia dawsoni* CLAPP & SHIMER, 1911, p. 431, Pl. 40, fig. 1, Pl. 42, fig. 16

*"Thecosmilia" dawsoni* STANLEY, 1979, Pl. 3, fig. 3

*Retiophyllia dawsoni* (Clapp and Shimer) MELNIKOVA AND BYCHKOV, 1986, fig. 2, Pl. 7, fig. 1

*Retiophyllia pascoensis* STANLEY, 1994b, Pl. 5, figs. 1-5, text-figs. 8 & 9
Material. – Two silicified specimens from the Chitistone Limestone MI 9934 (M1708) Wrangell Mountains, southcentral Alaska. Fifteen silicified fragments from Lake Cowichan MI 8302 and Pender Point MI 9947 Vancouver Island, Canada.

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<td>5</td>
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</tbody>
</table>

Description. – Small, densely packed colonies, dendroid integration, variably preserved epitheca, circular to slightly oval corallites. Three orders of septa closely spaced with no detail. S1 most prominent, extending ¾ of radius. S2 thinner, less abundant around the calice. S3 observed as small projection along endotheca. Silicification has obscured much corallite detail.

Discussion. – Clapp and Shimer (1911) originally identify *Calamophyllia dawsoni* from Lake Cowichan in Vancouver Island, Canada. Melnikova and Bychkov (1986) reaffirm the validity of this species by including it into the genus *Retiophyllia* Cuif. Stanley (1994) illustrates and describes in much detail a new species, *Retiophyllia pascoensis*,...
from Peru to which we place in synonymy. Our specimens have identical properties to
the holotype material for both *Retiophyllia dawsoni* (Clapp and Shimer) and *Retiophyllia
pascoensis* Stanley. In looking at the original publication by Clapp and Shimer (1911),
we find that both the description and illustration of *R. dawsoni* is vague and of poor
quality and therefore should be revised. Furthermore, the artistic rendition for this
species (Pl. 40, fig. 1) does not seem to match the illustration (Pl. 42, fig. 16). However,
Stanley (1994) gives detailed descriptions for colony shape, growth form and corallite
morphology and presents illustrations that highly resemble re-examined type material
from Clapp and Shimer (1911). For these reasons, we have concluded that *R. pascoensis*
Stanley should be placed in synonymy with the older species, *R. dawsoni* Clapp and
Shimer.

Stanley (1994) recognizes two growth forms or morphotypes for this species. The
first results in a broad, wide colony that is distinguished by low growing laterally inclined
branches or runners in which 5-6 closely spaced corallites may bud. The second
morphotype is distinguished by a densely packed phaceloid branching pattern, in which
runners are absent and growth is considered low and subparallel to the sediment surface.
Within our study northern Wrangellia (Wrangell Mountains) contained the second
morphotype of this species whereas southern Wrangellia (Lake Cowichan and Pender
Point on Vancouver Island) contained both growth forms.

Stanley (1994) maintains this species has similar septal arrangement and corallite
diameters to the Alpine species *R. oppeli* (Reuss) and similar corallite size to the Alpine
species *R. gracilis* (Roniewicz). However, *R. dawsoni* (Clapp and Shimer) differs from
*R. oppeli* (Reuss) by having greater septal density and fewer septa; it also differs from *R.
gracilis (Roniewicz) by having thinner epitheca and lower septal density. *R. pascoensis* (Stanley) highly resembles *Thecosmilia sublaevis* (Münster) illustrated in Volz (1896) Pl. 2, figs. 1-5 in growth form, calical dimensions, number of septa, septal density and thickness of epitheca.

**Occurrence.** – Lower Norian Wrangell Mountains, Alaska; Rhaetian Lake Cowichan, Pender Point Vancouver Island, Canada; Upper Triassic (Norian) from Pucará Group central Peru; Koryak Highlands, northeastern Russia.

**RETIOPHYLLIA cf. R. FRECHI Roniewicz, 1989**

(Plate 2, Figures 7, 8)

*Thecosmilia fenestrata* Reuss FRECH, 1890, p. 9, Pl. 1, figs. 25-27, Pl. 2, figs. 1-11, 13-17 (not fig. 12)

*Calamophyllia fenestrata* Reuss CUIF, 1965, p. 533, text-fig. 2 A

*Retiophyllia fenestrata* (Reuss) CUIF, 1967, p. 130, text-fig. 4 A, B, Pl. 4, fig. 4

*Retiophyllia fenestrata* (Reuss) CUIF, 1975, p. 369, text-figs. 33-35

*Retiophyllia frechi* RONIEWICZ, 1989, p. 48, Pl. 7, figs. 1-8, Pl. 9, fig. 5, Pl. 13, fig. 2

*Retiophyllia clathrata* (Emmrich) PRINZ, 1991, Pl. 1, fig. 4

*Retiophyllia frechi* Roniewicz 1989, p. 89, Pl. 4, figs. 5-9, text-fig. 7

**Material.** – Three silicified fragments from the Cornwallis Limestone Keku Strait MI 0099 (M1911), southeast Alaska.
Dimensions (in mm)

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<th>s / 3mm</th>
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**Description.** – Fragmented colonies, no apparent branching or budding. Epitheca worn, exposing distal septal edges with alternating thickness, no dissepiments. Two to three orders of septa preserved. S1 longer, wedge shaped, do not fuse forming columella. S2 thinner extend ½ to same length as S1. Dissepiments observed along endotheca, between S1 and S2 septa.

**Discussion.** – This identification is tentative because our material does not match descriptions by Roniewicz (1989) with respect to proper diameter and lack of connecting processes. However, a lateral view of our specimen reveals no dissepiments along epitheca and alternating septal thicknesses, which are in accordance to Roniewicz (1989, p. 49). Likewise, dissepiments do occur in our specimens along a transverse view of the corallite surface near the endotheca, which is also in accordance with descriptions from Roniewicz (1989).

**Occurrence.** – Norian from Keku Strait, southeast Alaska; Rhaetian from northern Calcareous Alps (Zlambach Beds of Fischerwiese, Hallstätter Salzburg, Zlambachgraben and Kesselwand-Rohrmoos).
RETIOPHYLLIA CF. R. NORICA (Frech, 1890)

(Plate 2, Figures 9, 10)

_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. ''fenestrate_" (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.** – Two silicified fragments from the Cornwallis Limestone Keku Strait MI 0099 (M1911) southeast Alaska. Four silicified fragments from the Chitistone Limestone Wrangell Mountains MI 9934 (M1708), southcentral Alaska.

<table>
<thead>
<tr>
<th>UMIP</th>
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<td>27x15x74</td>
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</table>

>Description.** – Poorly preserved phaceloid colony, obtuse bifurcation. Corallites circular and oval, with (rare) poorly preserved horizontal dissepiments along endotheca. Three to four orders of septa poorly preserved, thicker toward pellicular wall, microstructure obliterated. Septa along budding margin curve toward corallite upon budding (Pl. 2, fig.
9). S1 and S2 extend to the central axis, S1 thickest. S3 extend ½ - ¾ length of S1. S4 (rare, thin) exists near endotheca.

Discussion. – Identification of this species depended upon detailed morphological description by Roniewicz (1989). Specimens matched well with respect to corallite size, shape, septal arrangement and angle of bifurcation. Furthermore, our samples resembled illustrations by Frech (1890) (Pl. 1 fig. 14-24), Roniewicz (1989, Pl. 8 fig. 5-8) and Yarnell (2000). Identification of this species could not be based upon the microstructural details set forth by Roniewicz (1989) due to the replacement by silica which destroyed delicate microstructure.

Occurrence. – Keku Strait, Wrangell Mountains, Long Creek, Alaska; Pilot Mountains, Nevada; Lime Peak (Yukon), Canada; Sonora, Mexico; Zlambach beds, Austria.

RETIOPHYLLIA OPPELI (Reuss, 1864)

(Plate 2, Figures 14, 15)

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

Thecosmilia oppeli (Reuss), FRECH, 1890, p. 10, Pl. 2, figs. 18-20, 24, Pl. 3, figs. 4 A-E (not Pl. 2, figs. 21-23); VINASSA DE REGNY, 1915, p. 89, Pl. 69, figs. 7, 8;

MONTANARO-GALLITELLI et al., 1979, Pl. 4, fig. 2

Retiophyllia oppeli (Reuss, 1865), RONIEWICZ, 1989, Pl. 9, figs. 7, 8, Pl. 10, figs. 3, 4;

PRINZ, 1991, Pl. 1, fig. 5
Material. – A single silicified colony from the Chitistone Limestone Wrangell Mountains MI 9934 (M1708), southcentral Alaska.

<table>
<thead>
<tr>
<th>UMIP</th>
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<td></td>
<td></td>
<td>4</td>
<td>20</td>
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</table>

Description. – Phaceloid, uneven bifurcation, zigzag branches completely covered by unevenly thick epitheca. Corallites sub-circular or oval, calical depression 2-3 mm deep. Two to three orders of septa preserved around central axis or fissure. S1 thickest, wedge shaped, most prominent. S2 and S3 smaller, project ½ length of S1 septa.

Discussion. – *R. oppeli* is distinctive for its small corallite diameter and shape, frequent acute bifurcations, connecting processes and S1 septa being twice or three times as thick as S2 or S3 septa (Roniewicz, 1989). Our specimen displays matching morphology to the description of *R. oppeli* (Reuss), particularly the oval or circular shape of the corallites, general dimensions, uniquely thick S1 septa, as well as acute and frequent bifurcations. However, our specimen does not present any evidence of connecting processes, which differs with the description by Roniewicz (1989).

Montanaro Gallitelli et al. (1979, Pl. 4, fig. 2) illustrated a poorly preserved specimen from the Wrangell Mountains (M1708) identified as *Thecosmilia aff. T. oppeli* (Reuss, 1864), which our specimen (also from Wrangell Mountains) is virtually identical with; which, re-affirms the validity of this identification.
**Occurrence.** – Norian-Rhaetian of the Wrangell Mountains, SC Alaska; Lime Peak, southern Yukon, Canada; Hells Canyon, Oregon; Sonora, Mexico; northern Chile; Rhaetian of the northern Calcareous Alps (Zlambach Beds from Fischerwiese, Hallstätter Salzberg, Grosser Zlambachgraben and Kesselwand-Rohrmoos); Triassic of Indonesia.

**RETIOPHYLLIA cf. R. ROBUSTA Roniewicz, 1989**

(Plate 2, Figures 13, 19, 20)

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

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

**Material.** – Only two specimens from the Cornwallis Limestone Keku Strait MI 0099 (M1911), southeast Alaska.

<table>
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</table>

**Description.** – Colonies phaceloid poorly preserved. Pellicular wall thick, surrounding entire colony, thicker near each calice. Septa well preserved, three orders preserved. S1 thickest, protrude toward central axis. S2 septa ½ to ¾ length of S1, S3 rare.
Discussion. – Corallite diameter and number of septa of our specimens match, but are on the higher end of dimensions given by Roniewicz (1989). However, angle of bifurcation and colony shape seem to match her nonsilicified material. Furthermore, our specimens are poorly preserved in comparison to European samples. Therefore, this identification should be regarded as tentative until more material is available for study.

_Retiophyllia robusta_ Roniewicz was previously known only from Rhaetian deposits in the Alps (former Tethys) and unknown from North American and Canadian Cordilleran terranes. This first occurrence for _R. robusta_ Roniewicz (1989) is important when looking at global distribution of coral larvae.

Occurrence. – Lower Norian of Keku Strait, SC Alaska; Rhaetian of the northern Calcareous Alps (Zlambach Beds of Fischerwiese and Kesselwand-Rohrmoos).

**RETIOPHYLLIA SP. A**

(Plate 2, Figures 21-23, 25, 26, 29, 30)

_Thecosmilia cf. dawsoni_ (Clapp & Shimer) SQUIRES, 1956, p. 23, fig. 29-30

_Thecosmilia dawsoni_ (Clapp and Shimer) MONTANARO GALLITELLI et al., 1979, Pl. 4, fig. 1a, b

Material. – Three large silicified colonies and hundreds of fragments from Lake Cowichan Vancouver Island MI 8302, Canada. Twelve silicified fragments from the Chitistone Limestone Wrangell Mountains MI 9934 (M1708), southcentral Alaska.
### Dimensions (in mm)

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<tr>
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<th>s / 3mm</th>
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<tr>
<td></td>
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<td>6</td>
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<td>22</td>
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**Description.** – Colony dendroid, bush-like growth with densely packed corallites from frequent, acute, extracalicular budding or bifurcation, epitheca thin or non-existent. Calices sub-circular to oval occasionally quenched or constricted in comparison to other corallites. Connecting processes occur frequently between corallites and neighboring stalks (Pl. 2, fig. 21, 25). Two to three orders of septa, equal thickness extend toward calical center. S1 and S2 extend radius, S1 thicker, more pronounced, occasionally protruding above calical rim (in best preserved specimens) with possible ornamentation (Pl. 2, fig. 23, 30). S3 small, rare, wedge-shaped, projecting along pellicular wall.

**Discussion.** – This species occurs in abundance at Lake Cowichan in Vancouver Island, Canada. *Retiophyllia* sp. A has a similar corallite diameter and septal count as *R.*
clathrata (Frech) and has therefore been unrecognized in previous work. These two species co-occur within the *in situ* branching coral biofacies at Lake Cowichan, first described by Stanley (1989). We set this species apart from *R. clathrata* (Frech) because of marked differences in morphology such as growth form, occasionally quenched calices, corallite density and colony height. Growth form of *Retiophyllia* sp. A is low-growing or "bush-like" in which corallites readily branch and fan outward laterally keeping the colony spread out along the substrate. This is in opposition to *R. clathrata* (Frech), where corallites form long parallel stalks extending into the water column.

Specimens recovered from Squires (1956) and Montanaro Gallitelli et al. (1979) are highly fragmented and poorly preserved warranting tentative identifications; furthermore, illustrations show dimensions matching both *R. clathrata* (Frech) and *Retiophyllia* sp. A. However, growth form of these fragments seems to be similar with *Retiophyllia* sp. A. *R. clathrata* has a phaceloid growth form branching parallel whereas *Retiophyllia* sp. A is dendroid branching frequently.

**Occurrence.** – Rhaetian from Lake Cowichan Vancouver Island, Canada; Lewiston, Idaho; Lower Norian Wrangell Mountains, Alaska.

Subfamily CORYPHYLLIINAE Beauvais, 1981

Genus KUHNASTREA Cuif, 1976

*Type species.* – *Phyllocoenia decussate* REUSS, 1854

**KUHNASTREA DECUSSATA (Reuss, 1854)**

(Plate 1, Figures 15, 16, 18-20)
Phyllocoenia decussata REUSS, 1854, p. 99, Pl. 13, figs. 2, 3; FRECH, 1890, p. 28, Pl. 7, figs. 1-7, 9, 10 (non fig. 8); HAAS, 1909, p. 146, Pl. 5, fig. 6; CUIF, 1976, p. 78, text fig. 3, Pl. 3, figs. 1-6.

Isastrea whiteavesi CLAPP AND SHIMER, (part), 1911, Pl. 40, fig. 10 (not fig. 9)

Confusastrea descussata (Reuss) SMITH, 1927, Pl. 113, fig. 7, Pl. 115, figs. 1-3, Pl. 121, fig. 2

Confusastrea cf. C. descussata (Reuss) SMITH, 1927, Pl. 121, figs. 8, 9

Confusastrea cowichanensis Clapp and Shimer SMITH, 1927, Pl. 114, figs. 10-13

Palaeastraea descussata (Reuss) KOLOSVARY, 1966, Pl. 3, fig. 2; STANLEY, 1979, Pl. 4, fig. 4

Guembelastrea whiteavesi (Clapp and Shimer) MONTANARO GALLITELLI et al., (part), 1979, Pl. 5, figs. 6a, b

Kuhnastraea descussata (Reuss) STANLEY AND WHALEN, 1989, p. 808, figs. 5.5, 5.15, 7.1

Kuhnastraea decussata RONIEWICZ, 1989, p. 71, Pl. 14, fig. 3, Pl. 17, fig. 1, Pl. 18, figs. 1-2

Material. – Four specimens from the Cornwallis Limestone Keku Strait, southeast Alaska MI 0099 (M1911), and MI 0056 (M2135); twelve specimens from the Chitistone Formation Wrangell Mountains, southcentral Alaska MI 9934 (M1708).
Description. – Colonies lamellate to mound-shaped, pseudocerioid to cerioid. Corallite walls not shared between adjacent calices with regularly spaced and shallow calices. Septa synapticular, protruding into intercorallite depression. Three orders of septa preserved. S1 most pronounced, do not extend to calical center leaving open space. S2 extend ½ to full length of S1. S3 least pronounced, protruding only along endotheca.

Discussion. – Roniewicz (1989) gives detailed description of this species largely based on morphology but containing microstructural details imperative for proper identification. From her description, we find *K. decussata* comparable to *K. incrassata* (Frech, 1890) in colony growth form as well as corallite shape, septal arrangement and septal orders preserved; however, *K. decussata* differs from *K. incrassata* morphologically in corallite dimension, having larger corallite diameters. With regard for microstructural differences, our specimens are silicified and therefore do not present microstructure that is necessary in separating these species.
Morphologically, Roniewicz (1989) and Cuif (1976) maintain that subphaceloid or pseudoceroid integration (definite space between corallites) is a distinguishing characteristic of this Alpine species (Roniewicz, 1989, Pl. 18, fig. 1). Stanley and Whalen (1989) declare specimens from Hells Canyon, Oregon to have cerioid, compact, regularly arranged corallites with similar septal numbers, orders and thicknesses resembling a wedge or club shape. Furthermore, specimens of this genus seem to have a ring-like structure forming from both epitheca and endotheca (Roniewicz, 1989, Pl. 18, fig. 1).

From our study as well as others (Clapp and Shimer, 1911; Stanley and Whalen, 1989; Roniewicz, personal communication, 2004) there is clearly a separate variety of *K. decussata* found throughout the North American Cordillera. The North American variety contains compact, regularly spaced corallites with no real intercorallite space (Pl. 1, fig. 18-20; Stanley and Whalen, 1989, fig. 5.5, 5.15 and 7.1). The European variety is subphaceloid with large intercorallite spaces (Roniewicz, 1989, Pl. 18, fig. 1). This variety has similar corallite dimensions, prominent ring-like structures in corallites, and septal count, arrangement and thicknesses and as the North American variety. The European, more subphaceloid variety, has only been observed from one North American locality, MI 8302 at Lake Cowichan, Vancouver Island Canada (Pl. 1, fig. 15, 16). Clapp and Shimer (1911, Pl. 40, fig. 10) and Stanley (1979, 1989) have collected multiple colonies of this European variety.

*Occurrence.* – Rhaetian Vancouver Island, Canada; northern Calcareous Alps (Zlambach beds of Fischerwiese, Kesselwand-Rohrmoos, Hallstätter Salzberg, Zlambachgraben and
Scharitzkehralp, the latter three sites after Reuss 1854 and Frech 1890); Norian of Gravina Island, Keku Strait, southeast Alaska; Wrangell Mountains, southcentral Alaska; Iliamna Lake, Peninsular Alaska; Hells Canyon, Oregon; Shasta County, California; Pilot Mountains, Nevada.

**KUHNASTRAEA COWICHANENSIS (Clapp and Shimer, 1911)**

(Plate 1, Figures 21, 22)

*Isastrea cowichanensis* CLAPP AND SHIMER, 1911, p. 429, Pl. 41, fig. 11

*Confusastrea cowichanensis* (Clapp and Shimer). SMITH, 1927, Pl. 105, fig. 3, Pl. 114, figs. 10-13.

*Thamnastraea borealis* SMITH, 1927, Pl. 115, figs. 6, 7.

*Confusastrea borealis* SMITH, 1927, Pl. 116, figs. 1, 2.

*Phyllocoenia incrassata* (Reuss) SMITH, 1927, Pl. 121, fig. 2.

*Guembelastraea (?) cowichanensis* (Clapp and Shimer). MONTANARO GALLITELLI et al., 1979, Pl. 5, figs. 3a, b.

*Kuhastraea cowichanensis* (Clapp and Shimer). MELNIKOVA AND BYCHKOV, 1986, fig. 4, Pl. 5, fig. 3, Pl. 7, fig. 4; STANLEY AND WHALEN, 1989, 5.7, 5.12, 7.8, 7.15

**Material.** – Six specimens from the Cornwallis Limestone Keku Strait, southeast Alaska MI 0099 (M1911), MI 0056 (M2135), MI 0070; four specimens from the Chitistone Limestone southcentral Alaska MI 9934 (M1708); and two from the Sutton Limestone Lake Cowichan, Vancouver Island, Canada MI 8302.
**Description.** – Colonies mound shaped or platy, occasionally branching. Corallites circular or oval, oval on natural bend and circular along flatter portions. Corallite walls not shared, with variable intercorallite space. Prolonged costae tend to meet, but do not fuse in intercorallite depression. Corallite walls not well pronounced, suggesting asteroid integration. Calical depressions deep (1-2mm) sloping toward calical center, septa do not form columella.

Three to four orders of septa identifiable. S1 usually club-shaped, protrude $\frac{1}{2} - \frac{3}{4}$ to central axis. S2 shorter, thinner being $\frac{1}{2}$ length of S1 septa. S3 very thin identified as small projections along corallite wall. S1 and S2 have spiny ornamentation parallel to central axis (Pl. 1 fig. 22).

**Discussion.** – The type specimen, *Isastrea cowichanensis* Clapp and Shimer (1911), is vaguely described and poorly preserved by over silicification, lacking significant septal and corallite detail. However, many publications illustrate and describe specimens identified as (or in synonymy with) *K. cowichanensis* Clapp and Shimer from North
American terrane localities (Smith, 1927; Montanaro Gallitelli et al., 1979; and Stanley and Whalen, 1989). These specimens are placed within the genus *Kuhnastraea* Cuif, having similar morphological descriptions with European specimens. However, we feel sufficient morphological discrepancy exists for these specimens to not be identifiable as *K. decussata* or *K. incrassata*. Therefore, we have identified specimens as *K. cowichanensis* as having similar morphology, shape and dimensions as *K. incrassata*, but differ with regard to corallite spacing and amount of intercorallite space.

Roniewicz (1989) illustrates *K. incrassata* having rather large intercorallite spaces (Pl. 18, fig, 3) and notes *Palaeastraea*-like septal appearance. Frech (1890) distinguished the species *incrassata* from *decussata* by colony growth form, number of septa and structure of theca. In our silicified samples, we could not view the structure of the theca without thin sections, and ecological conditions such as water currents or wave action may influence growth form. Therefore we could only use number of septa and corallite size as distinguishing factors between species of this genus.

Stanley and Whalen (1989) mention North American terrane specimens have club or wedge shaped septa with three orders present (third order only exists close to the periphery of each corallite) forming a distinctive ring around the corallum upon cutting or weathering. Ring-structure forms from the thickening of septa toward the periphery of the corallum and is evident in illustrations by Frech (1890), Smith (1927), Roniewicz (1989) and Stanley and Whalen (1989). Rings are a distinctive characteristic that helps to define the genus in both European localities as well as in North American terrane localities. Our specimens match particularly well with the illustrations of Smith (1927) and Stanley and Whalen (1989, Fig. 5.1).
Occurrence. – Rhaetian from Vancouver Island, Canada; Lower Norian from Gravina Island and Keku Strait, southeast Alaska; Wrangell Mountains, southcentral Alaska; Hells Canyon, Oregon.

Family MARGAROPHYLLIIDAE Cuif, 1977

Genus MARGAROSMILIA Volz, 1896

Type species. – Montlivaltia zieteni KLIPSTEIN, 1843

MARGAROSMILIA CHARLYANA (Frech, 1890)

(Plate 3, Figures 1, 2, 5, 6)

Thecosmilia charlyana FRECH, 1890, p. 11, Pl. 3, figs. 5-5B, Pl. 5, figs. 6-7A

Margarosmilia charlyana (Frech, 1890) RONIEWICZ, 1989, p. 77, Pl. 19, figs. 1-4, Pl. 22, figs. 3, 4; STANLEY, 1994b, Pl. 5, figs. 6-8, Text-fig. 10

Material. – Four colonies from the Chitistone Limestone Wrangell Mountains, southcentral Alaska MI 9934 (M1708).
**Description.** – Colonies phaceloid, growing from central point of attachment with rugae epitheca surrounding entire colony. Individual branches fused except for calice, budding extracaliculary with flat and slightly elevated calices. Four orders of septa with equal thickness preserved around calical center. Septa do not fuse to form columella. S1 and S2 most prominent, extending radius, containing numerous, vertically oriented, jagged, pinnular structures along lateral surfaces. S3 and S4 shorter, reaching \( \frac{1}{4} \) to \( \frac{1}{2} \) length of S1 septa.

**Discussion.** – Gross morphology of our specimens match that of Stanley (1994). While septal detail and arrangement matches that of Roniewicz (1989) with respect to numerous, thin septa having strongly protruding granules differentiated into four orders; S1 and S2 being subequal in length.

Both authors describe this species with great morphological detail paying particular attention to the fused, closely spaced, multi-branching bifurcating or
trifurcating nature of the colony with sunken calices. Our specimens do not exhibit bifurcation or trifurcation (upon budding), sunken calices, and have diameters that are exceedingly too big. However, they do display free calices in each branch.

Roniewicz (1989) notes *M. zieteni* (adult individual) figured in Cuif (1975) to have diameters 13 X 16 mm, which match up perfectly with our specimens. Roniewicz (1989) further asserts similar septal structure between *M. zieteni* and *M. charlyana*. Our material superficially resembles a specimen illustrated by Laube (1865) as *Thecosmilia rugosa* Laube (Pl. 5, fig. 4) but contains much larger colony size.

**Occurrence.** – Lower Norian from Wrangell Mountains, southcentral Alaska; Norian from central Peru; and Norian-Rhaetian from the northern Alps.

**Margarosmilia cf. M. Richtofeni** Volz, 1896

(Plate 3, Figures 3, 4)

*Margarosmilia richthofeni* VOLZ, 1896, Pl. 1, figs. 15, 16

**Material.** – A single silicified colony from Keku Strait, southeast Alaska MI 0099 (M1911).

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<tr>
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<td>25x20</td>
<td>144</td>
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Description. – Colony mound-shaped, polycentric with linkages, growing on highly fragmented sphinctozoid sponge, thin epitheca. Corallites depressed, containing irregular shape, slightly flabellate, interconnected. Five orders of septa preserved, S1 slightly thicker. S1, S2 and S3 extend to central fissure, occasionally bending. Dissepiments occur sporadically between septa.

Discussion. – This identification is tentative based on original illustration by Volz, 1896 (Pl. 1, figs. 15, 16) and emended diagnosis of the genus by Roniewicz (1989). We place this specimen into genus *Margarosmilia* Volz because of its polycentric integration, numerous septa and linkages along the endotheca. However, our specimen does not possess prominent sharp spines which are another distinguishing factor of the genus. Only one specimen has been recovered from this study, presenting two moderately well preserved corallites.

Occurrence. – Lower Norian from Keku Strait, southeast Alaska; Carnian deposits in the Alps.

*Margarosmilia* cf. *M. Zieteni* (Klipstein, 1843)  

(Plate 3, Figure 7)  

*Montlivaltia zieteni* KLIPSTEIN, 1843, Pl. 20, fig. 1  

*Montlivaltia zieteni* (Klipstein, 1843) ÖSTL. ALPEN, 1845, p. 289, Pl. 20, fig. 1  

*Synastrea zieteni* D’ORBENY, 1849, p. 208
\textit{Thamnastrea goldfussi} MILNE EDWARDS et al., 1851, p. 113; GIEBEL, DEUTSCHL and PETREF., 1852, p. 189

\textit{Margarosmilia zieteni} (Klipstein, 1843) VOLZ, 1896, Pl. 1, figs. 1-7, text-fig. 18

\textit{Margarosmilia zieteni} (Klipstein, 1843) CUIF, 1974, fig. 29

\textit{Material}. – Five silicified fragments from the Chitistone Limestone Wrangell Mountains, southcentral Alaska MI 9934 (M1708).

\begin{table}
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UMIP & Colony & d & s & s / 3mm & s / 5mm & Remarks \\
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 & 5 & 22 & & & \\
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 & 5 & & & & \\
 & 15x11 & 6 & 24 & & & \\
 & 15x15 & 5 & 28 & & & \\
 & 5 & 26 & & & \\
\hline
\end{tabular}
\end{table}

\textit{Description}. – Colonies phaceloid and dendroid, branching acutely with circular, tapering corallites. Longitudinal section exposed by thin or missing epithea, dissepiments rare. Three to four orders of septa preserved around calical center. S1 (possibly S2) display ornamentation along lateral surfaces (Pl. 3, fig. 7) extending to central axis, not fusing to form columella. S3 (S4 rare) thinner, less pronounced, extend ¼ to ½ distance of S1 septa.
Discussion. – This identification is tentative based on illustrations by Volz (1896, Pl. 1, figs. 1-7) and limited material. General morphology match emended diagnosis of the genus given by Roniewicz (1989) with respect to phaceloid integration and ornamented septa with sharp spines. Material further matches illustrations by Volz (1896) with respect to colony size, dimensions of corallites and septal arrangement.

Occurrence. – Lower Norian from Wrangell Mountains, southcentral Alaska; Carnian from the Alps, Europe.

Genus DISTICHOMEANDRA Cuif, 1976

Type species. – Distichomeandra spinosa Cuif, 1976

DISTICHOMEANDRA AUSTRIACA (Frech, 1890)

(Plate 3, Figures 8, 9)

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.

Margarastrea 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. – A single specimen from the Cornwallis Limestone Keku Strait, southeast Alaska MI 0056 (M2135); two specimens from Vancouver Island, Canada MI 9913.

<table>
<thead>
<tr>
<th>UMIP</th>
<th>Colony</th>
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<th>s</th>
<th>s / 3mm</th>
<th>s / 5mm</th>
<th>Remarks</th>
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<td>4</td>
<td>6</td>
<td></td>
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<td>poorly preserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>3</td>
<td>10</td>
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<td></td>
<td>4</td>
<td>7</td>
<td>13</td>
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</table>

Description. – Colony pseudomeandroid, laminar with connected and individual calices. Corallites form long sinuous meanders with scattered, well-defined separated calices, defined by sharp walls. Two orders of thick, moderately well-preserved septa preserved frequently bending along central fissure, defining each corallum. S1 and S2 equal thickness, extending to central fissure.

Discussion. – Our sample matches well with the pseudomeandroid specimen illustrated in Frech (1890) and Roniewicz (1989, Pl. 20, fig. 1) and very well with a specimen.
illustrated by Yarnell (2000, Pl. 3, fig. 1). The illustrated material from Tahsis, Vancouver Island is well-preserved as a negative impression, brought out by latex molding. This specimen matches extremely well with illustrations in both Frech (1890) and Roniewicz (1989).

*Occurrence.* – Lower Norian from Keku Strait, southeast Alaska; Pilot Mountains, Nevada; Norian-Rhaetian from Lime Peak, southern Yukon, Canada; Sonora, Mexico; Rhaetian from Tahsis Inlet Vancouver Island, Canada; northern Calcareous Alps (Zlambach Beds of the Gasaukamm region and Fischerwiese).

**DISTICHOMEANDRA MINOR (Frech, 1890)**

(Plate 3, Figures 10, 11)

*Isastraea norica* var. *minor* FRECH, 1890, p. 26, Pl. 6, fig. 9

*Distichomeandra minor* (Frech). RONIEWICZ, 1989, p. 81, Pl. 20, figs. 2-5, Pl. 21, figs. 1, 2

*Material.* – Two silicified samples from the Cornwallis Limestone Keku Strait, southeast Alaska MI 0099 (M1911).
### Dimensions (in mm)

<table>
<thead>
<tr>
<th>UMIP</th>
<th>Colony</th>
<th>d or c-c</th>
<th>s</th>
<th>s / 3mm</th>
<th>s / 5mm</th>
<th>Remarks</th>
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<tr>
<td>228266</td>
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<td>5x5</td>
<td>38</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>8x8</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>228270</td>
<td>33x26</td>
<td>3</td>
<td>3</td>
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<td>3</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

**Description.** — Colonies laminar and mound-shaped, cerioid and pseudomeandroid integration. Calices sharp with well-defined walls, confluent septa. Septa extend to calical center forming papillate columella. Four orders of septa preserved with subequal thickness. S1 and S2 equal length extending to central axis or fissure. S3 $\frac{3}{2}$ length of S1 septa; S4 small only visible along endotheca.

**Discussion.** — This species was introduced by Frech (1890) as a minor variety of *Isastraea norica*. Roniewicz (1989) challenges this claim indicating that Frech’s species do not display structural characteristics in common with *Isastraea norica*. Further noting a high resemblance with *Distichomeandra austriaca* Frech but displaying distinct differences in microstructure and overall morphology, requiring separate species. *D. minor* differs from *D. austriaca* in that it has smaller, more lobate calices containing septa that have subequal thickness with more abundant septa and larger dissepiments connecting them. *D. minor* also resembles *Meandrostylis irregularis* Frech, 1890 in corallite size and shape. However, *M. irregularis* Frech has two elongate septa forming
parallel to each other along the central fissure of each meandering corallite (Roniewicz, 1989 Pl. 39, figure 10a & b).

**Occurrence.** – Lower Norian of Keku Strait, southeast Alaska; Rhaetian from the northern Calcareous Alps (Zlambach Beds of Fischerwiese and Kesselwand-Rohrmoos).

**Genus MARGARASTRAEA Frech, 1890**

We included the genus *Margarastraea* Frech into the family *Margarophyllidae* Cuif based on personal communication with Dr. Ewa Roniewicz (2004). Replacement by silica has destroyed septal microstructure of our material which is vital for proper placement of this genus into family *Margarophyllidae* Cuif.

Type species. – *Isastrea (Margarastraea) klimstein* FRECH, 1890

**MARGARASTRAEA cf. M. GRANDISSIMA (Smith)**

(Plate 3, Figures 22, 23)

*Confusastraea grandissima* SMITH (not Frech), 1927, p. 130, pl. 115, fig. 4.

*Margarastrea aff. deningeri* Wilkens MONTANARO GALLITELLI, RUSSO AND FERRARI, 1979, p. 148, Pl. 4, figs. 7a, b

**Material.** – Two silicified colonies from the Nehenta Formation Gravina Island, southeast Alaska MI 8831.
**Description.** — Colony massive, pseudomeandroid, poorly preserved covered by epitheca. Corallites oval, deep calices tapering to common point of attachment. Two orders of septa of subequal thickness preserved, extend toward calical center, do not form columella. S1 longer, reach half radius. S2 visible as small projections along periphery.

**Discussion.** — This specimen is superficially similar to *Confusastrea grandissima* Smith illustrated in Smith (1927, Pl. 115, fig. 4) identified as *Margarastraea aff. deningeri* Wilckens by Montanaro Gallitelli *et al.* (1979, Pl. 4, fig. 7) with respect to corallite size / shape and septal arrangement. We cannot place this species in synonymy with *M. deningeri* Wilckens (1937, Pl. 7, fig. 1) due to strong morphological differences with type material. We further note the coral from Smith (1927) and this new coral exhibit pseudomeandroid integration, oval corallites resembling petals of a flower and septal density in common with the genus *Margarastraea* Cuif. Therefore, we identify these coals as *Margarastraea grandissima* (Smith).

The type specimen of *M. deningeri* Wilckens is identical to *M. klipsteini* Frech (in Volz, 1896) with respect to size of each pseudomeandroid calice, septal count and overall growth form; therefore, *M. deningeri* Wilckens should be placed in synonymy with *M. klipsteini* Frech.

<table>
<thead>
<tr>
<th>UMIP</th>
<th>Colony</th>
<th>d</th>
<th>s</th>
<th>s / 3mm</th>
<th>s / 5mm</th>
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<td>18066</td>
<td>22x21x23</td>
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<td>3</td>
<td>5</td>
<td>fragment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>4</td>
<td>6</td>
<td></td>
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</table>
Occurrence. – Lower Norian, Gravina Island, Alaska.

Margarastrea klipsteini Freeh, 1890

(Plate 3, Figures 12, 13, 16, 17, 19)

*Margarastrea klipsteini* Freeh VOLZ, 1896, p. 55, Pl. 5, figs. 7a-d

*Margarastrea deningeri* WILCKENS, 1937, Pl. 7, fig. 1

*Margarastrea pulchra* Montanaro Gallitelli, 1979, p. 85, Pl. 3, Figs. 1-3, Text-fig. 5

Material. – Seven specimens from the Parson Bay Formation Lake Cowichan (MI 8302) and Tahsis Inlet (MI 9913) Canada.

<table>
<thead>
<tr>
<th>Dimensions (in mm)</th>
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<tr>
<td>UMIP</td>
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<td>--------</td>
</tr>
<tr>
<td>22068</td>
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</table>

Description. – Colony meandroid, laminar, layered multi-generational growth. Calices inter-connected, no walls or epitheca. Meanders organized in linear fashion with calical centers spread throughout colony. Septa shared between adjacent meanders, converge along central fissure, bending, accentuating calice. At least three orders of equally thick
septa preserved. S1, S2 prominent, extending entire length between adjacent meanders, terminating at each central fissure. S3 more granular, extend $\frac{3}{4}$ distance to each fissure. S4 (rare) highly resemble S3 septa.

Discussion. – Volz (1896) gives credit to Frech for the original identification of this species, however no synonymy is given within Volz (1896) indicating an illustration or description of this species from Frech (1890). Therefore, illustrations in Volz (1896) were used for identification of this species. Wilckens (1937) identifies a new species Margarastraea deningeri Wilckens which we place in synonymy with M. klipsteini Frech due to similar morphological characteristics i.e. corallite dimensions and septal arrangement, also verified by Dr. Ewa Roniewicz (personal communication, 2004).

Our specimens match well with the illustration in Volz (1896), in particular the long sinuous meandering arrangement of corallites without well-defined walls. M. klipsteini differs from the morphologically similar species M. pulchra Montanaro Gallitelli by having low-lying meanders connected by septa of equal thickness as opposed to sharply defined walls (or ridges) separating adjacent meanders (Stanley and Whalen, 1989, Figure 6.8).

Occurrence. – Rhaetian from Lake Cowichan, Tahsis Inlet Vancouver Island, Canada; Carnian from the Alps; Seran.

MARGARASTRAEA SP. A

(Plate 3, Figures 20, 21, 24, 25)
Diagnosis. – Colony pseudomeandroid, flabellate, epitheca rugae, corallum width 1.0 to 2.2 cm stalk 2.5 to 5.0 cm. Horizontal dissepiments occur along epitheca.

Material. – A single silicified colony from the Cornwallis Limestone Keku Strait southeast Alaska MI 0099 (M1911); Three juvenile colonies from the Chitistone Limestone Wrangell Mountains southcentral Alaska MI 9934 (M1708).

<table>
<thead>
<tr>
<th>UMIP</th>
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<th>d</th>
<th>s</th>
<th>s/3mm</th>
<th>s/5mm</th>
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<td>7</td>
<td>9</td>
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<td></td>
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<td>5</td>
<td>7</td>
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<td>Juvenile</td>
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<tr>
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<td>26x17x32</td>
<td>12</td>
<td>7</td>
<td>11</td>
<td></td>
<td>Juvenile</td>
</tr>
<tr>
<td></td>
<td>13x8x13</td>
<td>8</td>
<td>6</td>
<td>9</td>
<td></td>
<td>Juvenile fragment</td>
</tr>
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</table>

Description. – Colony pseudomeandroid, flabellate, stalk 2.5 to 5.0 cm long and 1.0 to 2.2 cm wide. Epitheca thin, rugae, surrounding colony, well preserved along inner wall of colony. Exposed longitudinal sections reveal horizontal dissepiments along the wall of the epitheca. Three to four orders of septa exist within large, deeply sunken calices; granular ornamentation along lateral surfaces. S1 bend as they approach central fissure, occasionally fuse to form individual corallites. S2 thinner extending $\frac{1}{2}$ length of S1 septa. S3 (and S4) exist as small projections about $\frac{1}{6}$ to $\frac{1}{4}$ size of S1 septa.

Discussion. – Roniewicz (1989) maintains the genus *Margarosmilia* Volz is phaceloid with numerous ornamented septa and a vesicular endotheca. Our specimens clearly do
not possess these characteristics and therefore cannot be considered of this genus.

Roniewicz (1989) considers the genus Distichomeandra Cuif to have cerioid and pseudomeandroid integration with septal ornamentation and smaller dimensions in comparison to our specimens. We place this new species in genus Margarastraea Frech, due to morphological similarities i.e. colony growth form and integration, corallite dimensions septal arrangement, thickness and density with other species of this genus. This species grows into the water column forming single, sinuous meanders without adjacent counterparts. This is different from M. klipsteini Frech and M. pulchra Montanaro Gallitelli, where colonies grow laminar, forming a network of adjacent sinuous meanders growing in either fan-shaped (M. pulchra) or plate-like (M. klipsteini) colony growth.

Occurrence. – Lower Norian from Keku Strait, southeast Alaska; Wrangell Mountains, southcentral Alaska.

MARGARASTRAEA SP. B

(Plate 3, Figures 14, 15, 18)

Diagnosis. – Colony thin, laminar, pseudomeandroid. Corallites large, shallow, 20 to 30 mm wide, 25 to 50 mm long. Four orders of septa present, S1 and S2 subequal length and thickness reaching central fissure. S3 and S4 shorter, thinner, projecting near endotheca.

Material. – A single silicified colony from the Nehenta Limestone Gravina Island, southeast Alaska MI 9938.
**Description.** — Colony thin, laminar, pseudomeandroid. Corallites large with well-defined walls, shallow calices and rugae epitheca. Extracalicular budding, separate juvenile buds fuse with parent colony upon growth. Septa poorly preserved, extend to calical center bending toward center. Three to four orders of septa preserved, partially covered by quartz grains. S1 and S2 septa most prominent, subequal thickness, extend entire radius. S3 and S4 thinner, extend $\frac{1}{4}$ to $\frac{1}{2}$ length of S1. S3 and S4 mostly covered, projecting near wall.

**Discussion.** — Our specimen superficially matches *M. klipsteini* Frech in Volz (1896, Pl. 5, fig. 7a-d) with respect to pseudomeandroid integration as well as septal thickness / arrangement, which are all characteristic of genus *Margarastrea* Frech (Roniewicz, 1989). However, our specimen has distinct differences making it a candidate for a new species. Abnormally large corallites are a unique and have not been formerly noted by other authors studying this genus. This coral also contains thick S1 septa that bend and curve while extending to the calical center. Roniewicz (1989) distinguishes this genus
from other pseudomeandroid genera throughout the Carnian / Norian by thick trabecular microstructure; however due to silicification, microstructure is not observed.

Occurrences. — Lower Norian, Gravina Island, Alaska.

Suborder FUNGIINA Verrill, 1865, *faute de mieux*

Superfamily PROCYCLOLITOIDEA Vaughan and Wells, 1943

Family ASTRAEOMORPHIDAE Frech, 1890

Genus ASTRAEOMORPHA Reuss, 1854

Type species. — *Astraeomorpha crassisepta* REUSS, 1854

**ASTRAEOMORPHA CRASSISEPTA** Reuss, 1854

(Plate 4, Figures 1, 2, 5, 6)

*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 GESSANT, 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; RONIEWICZ, 1974, p. 113, Pl. 9, figs. 4,5;

CUIF, 1975, p. 117, text-fig. 19, Pl. 17, figs. 1-7; MONTANARO GALLITELLI et al., 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,
1986, p. 56, Pl. 20, figs. 1-3, Pl. 21, fig. 2; MELNIKOVA AND BYCHKOVOV, 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. 3a

*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.* – Eight specimens from the Cornwallis Limestone Keku Strait, southeast Alaska MI 0087 (M1912), MI 0056 (M2135); four specimens from the Nehenta Formation Gravina Island, southeast Alaska MI 9935; fourteen samples from the Chitistone Formation Wrangell Mountains, southcentral Alaska MI 9934 (M1708); thirteen samples from the Sutton Limestone Lake Cowichan Vancouver Island, Canada MI 8302.
Description. — Colony thamnasteroid, flat, laminar to mound shaped, hemispherical and even columnar. Corallites densely packed, disorderly across surface. One to three septa shared between consecutive calices; calical center indicated by button-like columella. Septa thicker (0.5 mm), one to two orders recognizable, less abundant around corallum, do not fuse. S1 and S2 equal thickness, S1 shared between corallites, S2 exist between adjacent calices. S2 septa extend close to, same length as S1. S2 occasionally fuse with adjacent S2 septa from nearby colonies forming triple-junctions between calices (Pl. 4, fig. 6 arrow).

Discussion. — This species is one of the most well known species of Upper Triassic coral, found in many worldwide localities existing from Ladinian – Rhaetian time. Squires
(1956), has mistakenly assigned new species to this genus that cannot be distinguished from the type species by Reuss (1854). *Thamnastraea borealis* Smith (1927) has been reported synonymous with *A. crassisepta* Reuss in Montanaro Gallitelli *et al.* (1979) and Stanley and Whalen (1989). Our specimens match well with those from Squires (1956), Montanaro Gallitelli *et al.* (1979) and Stanley and Whalen (1989).

*Occurrence.* – Keku Strait, Gravina Island and Wrangell Mountains, Alaska; Hells Canyon, Oregon; Lewiston, Idaho; northern Peru; northern and southern Alps, Austria and Italy; Tatra mountains, Poland; middle Afghanistan; central Iran; northern Caucasus Mountains, Pamir Mountains, and Koryak Highland, Russia.

**ASTRAEOMORPHA CONFUSA** *(Winkler, 1861)*

(Plate 4, Figures 9, 10)

*Thamnastraea confusa* WINKLER, 1861, p. 488, Pl. 8, fig. 10

*Astraeomorpha confusa* Winkler FRECH, 1890, p. 67, Pl. 19 figs. 2, 3, 5, 6, 8, 10, 13

*Astraeomorpha confusa* Winkler major VINASSA DE REGNY, 1915, p. 103, Pl. 68, figs. 13-15

*Astraeomorpha confusa* (Winkler) Form B and C ZANKL, 1969, p. 26, text-figs. 15, 16

*Astraeomorpha crassisepta* Reuss MELNIKOVA, 1971, (part) p. 29, Pl. 1, figs. 1, 2; RONIEWICZ, 1974, p. 113, Pl. 9, figs. 4, 5; MELNIKOVA, 1975, (part) p. 116, Pl. 23, figs. 1-6, Pl. 24, figs. 1-3, Pl. 25, fig. 1, Pl. 26, fig. 3

*Astraeomorpha confusa* (Winkler) SCHÄFER, 1979, p. 46, Pl. 10, fig. 3; STANLEY, 1979, Pl. 1, 11
Astraeomorpha confusa minor Frech SENOWBARI-DARYAN, 1980, p. 38, Pl. 5, fig. 4

Astraeomorpha confusa confusa (Winkler) KRISTAN-TOLLMANN et al., 1980, p. 171, Pl. 4, fig. 3

Astraeomorpha confusa (Winkler) FANTINI-SESTINI & MOTTA, 1984, p. 352, Pl. 29, fig. 5; MATZNER, 1986, Pl. 9, fig. 2; MELNIKOVA, 1986, p. 57, Pl. 20, fig. 4, Pl. 21, fig. 1; RONIEWICZ, 1989, p. 96, Pl. 28, figs. 1, 2, Pl. 29, figs. 1-3; STANLEY, 1994b, p. 84, Pl. 2, figs. 5-6; MELNIKOVA, 2001, Pl. 23, fig. 4

Material. – A single silicified colony from the Nehenta Formation Gravina Island, southeast Alaska MI 9935; one colony from The Sutton Limestone Lake Cowichan Vancouver Island, Canada MI 8832.

Description. – Colony thamnasteroid, laminar. Corallites regularly arranged in rows along surface, extremely shallow calices and button-like columella at calical center. Three orders of septa of equal thickness meet at central axis, do not fuse, are shared between adjacent rows. S1 and S2 septa extend entire distance between adjacent columella. S1 bend toward nearest columella, S2 straighter, positioned close to adjacent calice. S3 situated between calices, do not extend entire distance.

Discussion. – A. confusa (Winkler) has been well documented in European and North American localities (Montanaro Gallitelli et al., 1979; Roniewicz, 1989; Stanley and Whalen, 1989). It closely resembles A. crassisepta Reuss in distance between calices, septal arrangement, colony integration and growth form. However, differs with respect
to corallite arrangement (in rows) as well as septal density (more dense). Also, septa from *A. confusa* (Winkler) are thinner than *A. crassisepta* Reuss but thicker than *Pamiroseris rectilamellosa* (Winkler). Roniewicz (1989) notes difficulties, in past descriptions, distinguishing between these two species; thus confirming *A. crassisepta* and *A. confusa* are probably closely related.

*Occurrence.* – Norian from Gravina Island, Alaska; Rhaetian from Vancouver Island, Canada; Norian – Rhaetian of the Alps, Caucasus, Central Asia and Timor.

Genus *PARASTRAEOMORPHA* Roniewicz, 1989

Type species. – *Parastraeomorpha minuscula* RONIEWICZ, 1989

**PARASTRAEOMORPHA SIMILIS** Roniewicz, 1989

(Plate 4, Figures 4, 8)

*Parastraeomorpha similis* RONIEWICZ, 1989, p. 99, Pl. 30, fig. 3; MEI.NIKOVA, 2001, p. 62, Pl. 24, fig. 1

*Parastraeomorpha* cf. *P. similis* Roniewicz, STANLEY, 1994b, Pl. 2, figs. 7-8

*Material.* – Two colonies from the Sutton Limestone Lake Cowichan Vancouver Island, Canada MI 8302.
## Dimensions (in mm)

<table>
<thead>
<tr>
<th>UMIP</th>
<th>Colony</th>
<th>d (c-c)</th>
<th>s</th>
<th>s / 3mm</th>
<th>s / 5mm</th>
<th>Remarks</th>
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<td></td>
<td>2.2</td>
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<tr>
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<td>14</td>
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<td></td>
<td>1.5</td>
<td>16</td>
<td></td>
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</tbody>
</table>

**Description.** — Colony laminar, sub-ceroid to thamnasteroid. Corallites randomly arranged along surface. Septa synapticular, slightly raised around rim, fusing with septa of adjacent corallites to form poorly developed pseudo wall. Three orders of septa moderately well-preserved. S1 and S2 septa equal thickness, extend towards the calical center, S1 meet to form small, poorly developed and easily mistakable columella; S3 rare, present as small projections along pseudo wall.

**Discussion.** — Our material matches well with dimensions and gross morphology including disorderly distribution of corallites along the colony surface as well as S1 septa meeting to form a small columella within the calice described by Roniewicz (1989) as well as illustrations by Stanley (1994). Stanley (1994) also notes a close relationship with *P. minuscula* Roniewicz, distinguished only by smaller calical dimensions.
Occurrence. – Rhaetian from Vancouver Island, Canada; northern Calcareous Alps (Zlambach Beds of Fischerwiese and Kesselwand-Rohrmooos); Norian from central Peru; Hells Canyon, Oregon.

Suborder ARCHAEOCOENIINA Alloiteau, 1952
Family ACTINASTRAEIDAE Alloiteau, 1952
Genus CHONDROCOENIA Roniewicz, 1989

Type species. – *Prionasraea schafhauèuti* WINKLER, 1861

**CHONDROCOENIA SCHAFHAEUTLI (Winkler, 1861)**

*(Plate 4, Figures 3, 7)*

*Prionasraea ? schafhauèuti* WINKLER, 1861, p. 488, Pl. 8, fig. 11.

*Isastraee Süssi* REUSS, 1865, p. 162, Pl. 2, fig. 4.

*Sephanocoenia schafhauèuti* 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 schafhauèuti* (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; STANLEY, 1986, Pl. 3.1, fig. 11.

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

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

*Astrocoenia schafhauèuti* (Winkler). SQUIRES, 1956 (as *A. schafhauèuti*), p. 9, figs. 1-3;

*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; STANLEY, 1994b, p. 86, Pl. 3, figs. 4-8; MELNIKOVA, 2001, p. 79, Pl. 27, figs. 2,3, Pl. 28, fig. 1

*Material.* – Three fragments from the Sutton Limestone Lake Cowichan Vancouver Island, Canada MI 8302.

<table>
<thead>
<tr>
<th>UMIP</th>
<th>Colony</th>
<th>d</th>
<th>s</th>
<th>s / 3mm</th>
<th>s / 5mm</th>
<th>Remarks</th>
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<tr>
<td></td>
<td></td>
<td>3</td>
<td>34</td>
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<td>N/A</td>
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</tr>
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<td>N/A</td>
<td>N/A</td>
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</table>

*Description.* – Colony cerioid, multi-serial, columnar; corallites circular, weekly defined walls. Calical depressions shallow, flat, with poorly defined columella. Three orders of nonconfluent septa moderately well preserved around calice. S1 thickest, extend entire
radius, fusing with columella. S2 extend ⅔ radius, thinner; S3 ⅓ to ⅓ length of S1, occasionally same thickness as S2.

**Discussion.** – Corallite dimensions and general morphology match very well with specimens from Stanley (1986, 1994), Roniewicz (1989), and Melnikova (2001). However, our specimens exhibit a columnar growth form whereas other specimens are lamellate or hemispherical. Roniewicz (1989) mentions colonies rarely branch, with individual branches up to 20 mm in diameter and 70 mm in length.

Specimens from Lake Cowichan are fragmented from longer branches. Corallite morphology has been obliterated from etching in HCl in two of three recovered specimens and has therefore been excluded. Likewise, microstructural details have not been preserved due to silicification.

**Occurrence.** – Rhaetian from Lake Cowichan, Vancouver Island; Lewiston, Idaho; northern Calcareous Alps, Southern Alps (Lombardy) and Carpathians; Norian-Rhaetian from the Pamirs and Afghanistan; Norian from Peru.

**CHONDROCOENIA cf. C. PARADOXA** *(Melnikova, 1968)*

(Plate 4, Figures 11, 12)

*Cyathocoenia paradoxa* MELNIKOVA, 1968, p. 16, Pl. 3, fig. 1,2; 1975, p. 61, Pl. 2, fig. 1-3, 6, Pl. 3, fig. 1; STANLEY AND WHALEN, 1989, p. 814, Fig. 6.3.
Material. – A single silicified colony from the Chitistone Limestone Wrangell
Mountains, southcentral Alaska M1708.

<table>
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<tr>
<th>UMIP</th>
<th>Colony</th>
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<th>s</th>
<th>s / 3mm</th>
<th>s / 5mm</th>
<th>Remarks</th>
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<td>16</td>
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<tr>
<td></td>
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<td>14</td>
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</tr>
<tr>
<td></td>
<td>4</td>
<td>22</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>19</td>
<td></td>
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<tr>
<td></td>
<td>4</td>
<td>19</td>
<td></td>
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</tr>
</tbody>
</table>

Description. – Colony fragmented, laminar. Corallites polygonal spaced regularly,
poorly-defined unshared walls. Two orders of synapticular septa surround corallum; S1
most pronounced, extend entire radius, S2 thinner visible along endotheca.

Discussion. – Our specimen is identical to Cyathocoenia paradoxa Melnikova in Stanley
and Whalen (1989, Fig. 6.3). We follow Roniewicz (1989) by including the species
paradoxa into genus Chondrocoenia Roniewicz. However, because we only have one
specimen for study, this identification should be regarded as tentative.

Occurrence. – Lower Norian from Wrangell Mountains, Alaska; Hells Canyon, Oregon;
Pamir Mountains.
Suborder ASTRAEOINA Alloiteau, 1952

Family PAMIROSERIIDAE Melnikova, 1984

Genus PAMIROSERIS Melnikova, 1971

Type species. – *Thamnastraea meriani* STOPPANI, 1860

**PAMIROSERIS MERIANI (Stoppani, 1858 – 1860)**

(Plate 4, Figures 13-16, 19, 20)

*Thamnastraea meriani* STOPPANI, 1858 – 1860, p. 108, Pl. 26, figs. 3-6; REUSS, 1865, p. 163, Pl. 3, fig. 2.

*Confusastraea (adelastraea) delicate* REUSS, 1865, p. 162, Pl. 2, figs. 1, 2.

*Thamnastraea delicate* FRECH, 1890, p. 63, Pl. 17, figs. 9-11.

*Pamiroseris meriani* MELNIKOVA, 1971, p. 34, Pl. 11, fig. 2; 1975, p. 125, Pl. 30, figs. 3-5, Pl. 31, fig. 1, Pl. 32, figs. 1-3.

*Pamiroseris meriani* (Stoppani, 1858 – 1860). MONTANARO GALLITELLI et al., 1979, p. 140, Pl. 1, figs. 7a, b.

*Pamiroseris meriani* MELNIKOVA AND BYCHKOV, 1986, p. 64, Pl. 25, figs. 3-6, Pl. 26, figs. 1-3.

*Pamiroseris meriani* (Stoppani). MELNIKOVA, 2001, p. 74, Pl. 24, fig. 4, Pl. 29, figs. 2-4.

**Material.** – Eight specimens from the Chitistone Limestone Wrangell Mountains, southcentral Alaska MI 9934 (M1708); three samples from the Cornwallis Limestone Keku Strait, southeast Alaska MI 0099 (M1911) and MI 0056 (M2135).
### Dimensions (in mm)

<table>
<thead>
<tr>
<th>UMIP</th>
<th>Colony</th>
<th>d (c-c)</th>
<th>s / 3mm</th>
<th>s / 5mm</th>
<th>Remarks</th>
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<tr>
<td></td>
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<td>7.5</td>
<td>29</td>
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<tr>
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<td></td>
<td>8</td>
<td>18</td>
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<td>7</td>
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<tr>
<td></td>
<td></td>
<td>4</td>
<td>28</td>
<td></td>
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</tr>
<tr>
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<td></td>
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<td>22</td>
<td></td>
<td>juvenile</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5</td>
<td>14</td>
<td></td>
<td>juvenile</td>
</tr>
<tr>
<td>302895</td>
<td>35x26x10</td>
<td>7</td>
<td>25</td>
<td></td>
<td>colony growing on Stromatomorpha californica Smith</td>
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<tr>
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<td></td>
<td>7.5</td>
<td>26</td>
<td></td>
<td>35mm high</td>
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</table>

*Description.* — Colony thamnasteroid, flat, mound-shaped, occasionally using spongiomorphs or other organisms as substrate. Corallites slightly elevated, circum-oral (fungiform), calices shallow, budding extracaliculary indicated by three juvenile corallites growing separately and fusing upon maturity (Pl. 4 figs. 13, 15). Four orders of septa preserved extending toward the central axis. S1 (sometimes S2) shared between adjacent corallites occasionally bending. S1 septa blade-like, thickest in middle (0.5mm thick), thinner between corallites, extend to calical center and fuse forming columella. S2
extend entire length of S1 but thinner not forming columella. S3 extend \( \frac{1}{2} \) to \( \frac{3}{4} \) length of S1, same thickness as S2. S4 (rare) only appear along periphery.

Discussion. – Our specimens match well with those illustrated in Montanaro Gallitelli et al. (1979) and Stanley and Whalen (1989), who illustrated and briefly described specimens from localities in North America. Montanaro Gallitelli et al. (1979) describe *Pamiroseris meriani* (Stoppani) is easily recognizable based on thamnasteroid integration and circum-oral budding. Stoppani (1858) originally described the species to which Melnikova (1971) revised into genus *Pamiroseris* Melnikova. Roniewicz (1989) gives morphological and microstructural characteristics unique to the genus indicating pearl-like ornamentation (or granulation) along septal surfaces, partial columella, abundant dissepiments along endotheca and rare synapticulae. The presence of this species within the Alexander terrane and Wrangellia helps to extend the already broad geographic range of this species within the terranes of the North American Cordillera.

Occurrence. – Lower Norian from Keku Strait, Wrangell Mountains, Alaska; Snake River Idaho; Hells Canyon, Oregon; Alps, Italy; Southeastern Pamirs; Esino (Lombardia) Italy.

Genus CRASSISTELLA Roniewicz, 1989

Type species. – *Stephanocoenia juvavica* FRECH, 1890

**CRASSISTELLA JUVAVICA** (Frech, 1890)

(Plate 4, Figures 17, 18, 22)
Astrocoenia nov. sp. FRECH, 1890, p. 36, text-fig. on p. 36

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

I. sastraea profunda SMITH (not Reuss), part, 1927, p. 128, Pl. 114, fig. 2

I. sastraea parva SMITH, 1927, p. 128, Pl. 114, fig. 9

Tropiastraea carinata CUIF, 1967, Pl. 33a, figs. 6-8

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

Cyathocoenia parva (Smith, 1927) MONTANARO GALLITELLI, RUSSO AND FERRARI, 1979, Pl. 1, figs. 6a, 6b

Cyathocoenia aff. C. carinata (Cuif, 1967). MONTANARO GALLITELLI et al., 1979, p. 138, Pl. 1, figs. 3a-4b

Actinastraea juvavica (Frech). SENOWBARI-DARYAN, 1980, p. 42, Pl. 5, fig. 3;

WURM, 1982, p. 218, Pl. 34, fig. 6

Actinastraea juvavica (Frech). 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

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

Rhaetiastraea cf. R. vesiculosa (Melnikova in Melnikova and Bychkov, 1986)

STANLEY AND WHALEN, 1989, figs. 7.3, 7.4 and 7.5

Crassistella juvavica (Frech). MELNIKOVA, 2001, p. 76, Pl. 28, figs. 4, 5
Material. – Twenty-seven specimens from the Cornwallis Limestone Keku Strait, and Nehenta Limestone Gravina Island, southeast Alaska MI 0099 (M1911), MI 0087 (M1912), MI 0074 (M2136), MI 0056 (M2135), MI 9932; fifteen specimens from the Chitistone Limestone Wrangell Mountains, southcentral Alaska MI 9934 (M1708).

<table>
<thead>
<tr>
<th>UMIP</th>
<th>Colony</th>
<th>d</th>
<th>s</th>
<th>s / 3mm</th>
<th>s / 5mm</th>
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<td></td>
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<td></td>
<td>3</td>
<td>22</td>
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</tr>
</tbody>
</table>

Description. – Colonies laminar encrusting or massive hemispherical, cerioid. Corallites polygonal, often elongated along curvatures with sharp distinct walls. Two to three orders of septa preserved, non confluent, extend to calical center, smaller orders adhere to lateral surfaces of larger size order septa. S1 and S2 fuse to form styliform columella. S1 thicker, wedge-shaped, extend to columella. S2 thinner, extend to columella; S3 (rare) project along wall.
Discussion. – This species is one of the most abundant species from the Alexander terrane and Wrangellia. Our specimens match well with those illustrated as *Cyathocoenia aff. C. carinata* Cuif in Montanaro Gallitelli et al. (1979) with respect to corallite size and shape. Due to similar morphology and through personal communication with Dr. Roniewicz (2004), we place *Cyathocoenia aff. C. carinata* Cuif illustrated in Montanaro Gallitelli et al. (1979, Pl. 1, figs. 6a, 6b), *Isastraea profunda* Reuss illustrated in Smith (1927, Pl. 114, fig. 2), *Astrocoenia martini* Smith illustrated in Smith (1927, Pl. 115 fig. 5) and *Isastraea parva* Smith illustrated in Smith (1927, Pl. 114, fig. 9) in synonymy with *Crassistella juvavica* (Frech). Cuif (1972) argued the validity of genus *Cyathocoenia* Duncan in the Triassic, due in large part to microstructure of the coral. Cuif’s findings were verified by Roniewicz (1989) with the division into two genera *Crassistella* Roniewicz and *Chondrocoenia* Roniewicz. Although microstructural details are not preserved from our specimens, unique corallite shape, septal arrangement, and presence of columella enable solid identifications with Roniewicz (1989) and illustrations in Melnikova (2001).

Growth form is highly variable in material from the Alexander terrane and Wrangellia. An encrusting growth form is evident from sedimentary environments of higher energy deposition Gravina Island MI 9932; possibly because growth of the colony cannot keep up with sediment input in this area. More lamellate, massive and hemispherical growth form is evident from Keku Strait MI 0099, MI 0056 and Gravina Island MI 9936. This may be due to deeper water environments, calmer water in a more
reef-like environment or more time with which to grow these colonies due to low sediment input.

Prior to this study, *Crassistella juvavica* Roniewicz had only been observed from the Norian and Rhaetian deposits in Europe, Pamirs and NE Asia. The occurrence of this species and associated synonymies from the terranes of the North American Cordillera is an important link with the former Tethys Sea.

*Occurrence.* – Lower Norian from Gravina Island, Keku Strait, Wrangell Mountains, Alaska; Hells Canyon, Oregon; Shasta County, California (Bear Cove and Brock Mountain); northern Calcareous Alps (Zlambach beds of Schneckengraben and Kesselwand-Rohrmoos, Fischerwiese, Austria); Gruber Reef; Pamirs, and NE Asia.

**CRASSISTELLA PARVULA (Melnikova, 1982)**

(Plate 4, Figures 23, 24)

*Toechastraea plana parvula* DRONOV et al., 1982, p. 119, Pl. 16, figs. 6-9;

MELNIKOVA, 1986, p. 56, Pl. 19, fig. 3

*Material.* – A single silicified colony from the Cornwallis Limestone Keku Strait, southeast Alaska MI 0099 (M1911).
**Dimensions (in mm)**

<table>
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<tr>
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</table>

**Description.** – Colony plate-like with multiserial columnar growth protruding from center of plate. Corallites cerioid, polygonal, walls sharp, calices moderately deep. Natural curvature of colony distorts corallite shape. Septa well preserved to three orders extending to calical center occasionally fuse to form columella (S1). S1 extend radius. S2 extend ½ length of S1; S3 extend ¼ length of S1.

**Discussion.** – Corallite diameter and septal count are major characteristics that help to distinguish species within genus *Crassinella* Roniewicz. *C. parvula* (Melnikova) has the smallest diameter and number of septa; *C. vesiculosa* (Melnikova in Melnikova and Bychkov) has the largest dimensions, while *C. juvatica* Roniewicz is between the two.
Our specimen is comparable to *C. parvula* (Melnikova) illustrated in Melnikova (2001), specifically with respect to corallite diameters and septal count.


**CRASSISTELLA VANCOUVERENSIS (Clapp and Shimer, 1911)**

(Plate 4, Figures 21, 25-27)

*Isastraea vancouverensis* (Clapp and Shimer, 1911), SMITH, 1927, Pl. 112, figs. 1, 2.

*Isastraea profunda* (Reuss), SMITH, 1927, figs. 5, 6.

*Elysastraea profunda* (Reuss), SQUIRES, 1956, fig. 48

*Gablouzeria profunda* (Reuss), STANLEY, 1986, Pl. 3.1, fig. 14

*Chondrocoenia schafhaeutli* (Winkler, 1861), STANLEY, 1994b, Pl. 3, fig. 5, 6

_Material._ – Four specimens from the Cornwallis Limestone Keku Strait, southeast Alaska MI 0087 (M1912); one sample from the Nehenta Limestone Gravina Island, southeast Alaska MI 9935, MI 9933; twenty colony fragments from the Sutton Member Lake Cowichan Vancouver Island, Canada MI 8302.
<table>
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<tr>
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<th>s</th>
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<td></td>
<td>3</td>
<td>21</td>
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</tbody>
</table>

**Description.** – Colony laminar, encrusting. Corallites cerioid, strongly polygonal, highly variable in diameter, calices deep, budding intercalically; walls well-defined, sharp, thin, and steep. Two orders of non-confluent septa, subequal in thickness and length preserved as small projections along the periphery of each corallite. Septa extend to the central axis along floor of calice meeting to form poorly developed columella. At top of corallite, septa do not project into calical center, leaving large, deep calice.

**Discussion.** – Though only five well preserved colonies were recovered from our study area, many specimens of this species have been previously misidentified by other workers and included into the diagnosis. Squires (1956, fig. 48) and Stanley (1986, Pl.
(Reuss) from Idaho. Variation in corallite size of these specimens is characteristic of *G. profunda* (Reuss) however, the steep, sharp corallite walls and deep calical depression do not agree with genus *Gablonzeria* Cuif. Stanley (1994) identified a specimen as *Chondrocoenia schafhaeutli* (Winkler) from Peru (Pl. 3, fig. 5, 6). This sample is remarkably identical to our material with respect to septal arrangement, thickness and length extremely steep and sharp corallite walls with deep calical depression. Stanley (1994) further notes incredible variation in corallite size, which is uncharacteristic of *Chondrocoenia schafhaeutli* (Winkler); however, other specimens illustrated in this same publication do show affinities with genus *Chondrocoenia* Roniewicz described in Roniewicz (1989, p. 103).

*Occurrence.* – Lower Norian from Keku Strait, Gravina Island, Alaska; Mission Creek, Idaho; Shasta County, California; Norian from Pucará Group, Peru.

Genus AMPAKABASTREA Alloiteau, 1957

Type species. – Ampakabastraea ampakabensis ALLOITEAU, 1957

**AMPAKABASTREA cf. A. NODOSA Cuif, 1976**

(Plate 5, Figures 1, 2)

*Ampakabastraea nodosa* CUIF, 1976, p. 89, Pl. 5, figs. 1-3

*Ampakabastraea aff. nodosa* Cuif. MONTANARO GALLITELLI et al., 1979, p. 142, Pl. 3, fig. 1
Material. – Four fragments from the Chitistone Limestone Wrangell Mountains, southcentral Alaska MI 9934 (M1708).

<table>
<thead>
<tr>
<th>UMIP</th>
<th>Colony</th>
<th>d</th>
<th>s</th>
<th>s / 3mm</th>
<th>s / 5mm</th>
<th>Remarks</th>
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<td>26</td>
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</tbody>
</table>

Dimensions (in mm)

Description. – Colonies fragmented, moderately well-preserved. Corallites cerioid, calices moderately deep tapering, walls shared with synapticular septa extending to calical center. Three to four orders of septa preserved. S1 extend to central axis fusing forming pseudo-columella. S2 extend to axis but do not fuse; S3 and S4 small found along periphery.

Discussion. – Our material matches well with and is from the same locality as those illustrated in Montanaro Gallitelli et al. (1979). A tentative identification is necessary for this species, due to only superficial similarities with the illustrated type material in Cuif (1976) such as septal arrangement, corallite size and shape as well as limited material for study from the Wrangell Mountains. Type material in Cuif (1976, Pl. 5, fig. 1) does not have shared corallite walls and has a slight appearance of shared septa between adjacent calices, to which our specimens (and those from Montanaro Gallitelli et al., 1979) have shared corallite walls, with S1 septa meeting along the central axis forming a pseudo-columella.
Occurrence. – Lower Norian from Wrangell Mountains, southcentral Alaska; localities from Cuif (1976).

Genus THAMNASTERIOMORPHA Melnikova, 1971

Type species. – Thamnastraea frechi VOLZ, 1896

THAMNASTERIOMORPHA FRECHI (Volz, 1896)

(Plate 5, Figures 3, 4)

Thamnastraea frechi VOLZ, 1896, p. 59, Pl. 6, figs. 1-10

Thamnastraea borealis SMITH, 1927, Pl. 115, figs. 6, 7

Thamnastraea rectilamellosa SQUIRES (not Winkler), 1956, p. 4

Thamnasteriomorpha frechi (Volz) MELNIKOVA, 1975, p. 165

Thamnotropis frechi (Volz) CUIF, 1976, p. 121, Pl. 18, figs. 1-4, text-fig. 20

Thamnasteriomorpha frechi (Volz) MONTANARO GALLITELLI, RUSSO AND FERRARI, 1979, p. 141, Pl. 2, figs. 3a-4

Material. – Two specimens from the Cornwallis Limestone Keku Strait MI 0056 (M2135) and seven samples from the Nehenta Limestone Gravina Island MI 9931, southeast Alaska.
Dimensions (in mm)

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</table>

*Description.* — Colony columnar, multiserial. Corallites thamnasteroid, regularly spaced, with shallow calices. Two orders of confluent septa present and shared between calices. S1 septa longer, extend entire between adjacent calices, do not fuse to form columella; S2 shorter than S1 and typically make up most of intercorallite space.

*Discussion.* — Our material is identical to Gravina Island specimens by Smith (1927) and Montanaro Gallitelli *et al.* (1979). Unique thamnasteroid integration and definitive corallite walls characterizes this species. We follow Roniewicz (1989) instead of Montanaro Gallitelli *et al.* (1979) by placing genus *Thamnasteriomorpha* Melnikova into family Pamiroseriidae Melnikova and not into family Thamnasteriidae Vaughan & Wells. Montanaro Gallitelli *et al.* (1979) place genera *Pamiroseris* Melnikova and *Thamnasteriomorpha* Melnikova within family Thamnasteriidae Vaughan & Wells.
Occurrence. – Lower Norian from Keku Strait, Gravina Island, Alaska; Cow and Cedar creeks, Ingot, Shasta County, Brock Mountain, California; Norian from Austria (Fischerwiese); Carpathian, Balkans; Pamirs; Karakorum, Pakistan; Rhaetian from Lewiston, Idaho.

Genus ELYSASTRAEA Laube

ELYSASTRAEA FISCHERI Laube, 1865

(Plate 5, Figures 5, 6, 9, 10)

_Elysastraea fischeri_ LAUBE, 1865, p. 262, Pl. 5, fig. 6

_Iasiastra haueri_ LAUBE, 1865, p. 263, Pl. 7, fig. 1

_Iasiastra haueri_ (Laube) VOLZ, 1896, Pl. 4, figs. 10-12, 14, 15; CUIF, 1976, p. 109, Pl. 10, fig. 1-5, text-fig. 11.

Material. – Nine colonies from the Chitistone Limestone Wrangell Mountains, southcentral Alaska MI 9934 (M1708); one colony from the Cornwallis Limestone Keku Strait, southeast Alaska MI 0099 (M1911).
Dimensions (in mm)

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<td>juvenile</td>
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Description. – Colony mound shaped, lamellate. Corallites cerioid, sub-spherical, oval and highly polygonal with deep calices (3 mm). Calical diameter highly variable, frequent budding produces pseudomeandroid appearance. Two to Three orders of well-preserved septa extend toward calical center. S1 longest, most pronounced, wedge shaped, thickening toward wall, curved toward central axis. S2 thinner, wedge-shaped, extend ½ to ¾ length of S1; S3 extend ¼ distance of S1, recognized along wall.

Discussion. – Our material is identical to *Elysastraea fischeri* Laube illustrated in Laube (1865, Pl. 5, fig. 6). Volz (1896) placed *Elysastraea fischeri* Laube in synonymy with *Isastraea haueri* Laube to which Cuif (1976) followed suit. This identification is
problematic, because genus *Iasastraea* Milne-Edwards and Haime has been found to be invalid within Triassic time (Cuif, 1976; Roniewicz, 1989). Therefore, massive division of genus *Iasastraea* has occurred. Roniewicz (1989 p. 15) summarizes the division of genus *Iasastraea* into many Upper Triassic (Carnian to Rhaetian) genera. However, no author to date has dealt with Carnian material previously assigned to this genus. Furthermore, Roniewicz (1989, p. 15, 109) considers the genus *Elysastraea* Laube valid throughout the Carnian to Norian of the Triassic; noting this genus, along with many other Triassic genera, to have thick trabeculae as a distinguishing feature.

As a result, we cannot follow Volz (1896) and Cuif (1976) by assigning the species *haueri* to genus *Iasastraea* Milne-Edwards and Haime, and therefore, we refer back to the type material of Laube (1865) by identifying these specimens as *Elysastraea fischeri* Laube.

**Occurrence.**—Norian from the Wrangell Mountains, southcentral Alaska; Carnian from European localities.

**ELYSASTRAEA MINOR** (Vinassa de Regny, 1915)

(Plate 5, Figures 7, 8, 11, 12, 17, 18)


**Material.**—A single silicified specimen from the Chitistone Limestone Wrangell Mountains, southcentral Alaska MI 9934 (M1708).
Description. – Colony columnar, branching, multi-serial. Corallites cerioid to sub-meandroid, occur regularly, highly polygonal with shared, sharp walls and moderately deep calices. Septa preserved to three orders, confluent, match up well against shared wall, extend to calical center or fissure (when sub-meandroid) forming pseudo columella. S1 and S2 subequal thickness. S1 extend entire radius, most pronounced, granular ornamentation may be due to preservation, not natural. S2 extend ½ to entire length of S1, fusing to pseudo columella when length permits. S3 wedge-shaped project along wall, extend ¼ length of S1.

Discussion. – Our colony matches well with "I." haueri Laube illustrated in Laube (1865, Pl. 7, fig. 1) with respect to general morphology and colony appearance. However, our specimen contains corallites with much smaller diameters. We also note similarities (including corallite diameter) with Isastraea haueri Laube var. minor Vinassa de Regny (1915, Pl. 71, fig. 5, 6). However, this identification is problematic due to arguments in Cuif (1976) summarized in Roniewicz (1989), stating genus Isastraea

<table>
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<th>s / 3mm</th>
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<td>3.5</td>
<td>37</td>
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</table>
Laube is no longer considered valid within Triassic time, and therefore is in need of revision. We further note our specimen along with illustrations by Laube (1865) and Vinassa de Regny (1915) to have morphological similarities with genus *Elysastraea* Laube and should therefore be considered a species minor within this genus.

*Occurrence.* – Lower Norian from the Wrangell Mountains, SC Alaska; Timor; localities from Laube (1865).

Genus *RECTICOSTASTRAEA* Stanley and Whalen, 1989

Type species. – *Recticostastraea wallowaensis* STANLEY AND WHALEN, 1989

**RECTICOSTASTRAEA WALLOWAENSIS** Stanley and Whalen, 1989

(Plate 5, Figures 13-16)

*Andrazella* sp. MONTANARO GALLITELLI et al., 1979, Pl. 5, fig. 2a-c

*Recticostastraea wallowaensis* STANLEY AND WHALEN, 1989, p. 811, Figs. 6.6, 6.7

*Material.* – Four specimens from the Sutton Limestone MI 8302 at Lake Cowichan, Vancouver Island.
Description. — Colony laminar, plate-like, low-growing. Corallites meandroid forming series of parallel to subparallel, deep, narrow sinuous meanders defined by sharp septothecal ridges. Two orders of septa subequal in thickness and length, preserved extending ¾ to entire way towards central fissure.

Discussion. — Our specimens are identical to type material of Stanley and Whalen (1989, Figs. 6.6, 6.7) with respect to colony size, number of septa arrangement of meanders and distance between ridges. This species (to date) is endemic to the North American Cordillera, only being recognized from Hells Canyon, Oregon by Stanley and Whalen (1989) and Snake River, Idaho by Montanaro Gallitelli et al. (1979, Pl. 5, fig. 2). The occurrence of this species from southern Wrangellia Lake Cowichan, Vancouver Island is an important link between southern Wrangellia and the Wallowa terrane.
Occurrence. – Rhaetian from Vancouver Island, Canada; Norian from Hells Canyon, Oregon; Snake River, Idaho.

Suborder STYLOPHYLLINA Beauvais, 1981
Family STYLOPHYLLIDAE Frech, 1890
Genus STYLOPHYLLUM Reuss, 1854

Type species. – *Stylophyllum polyacanthum* REUSS, 1854

**STYLOPHYLLUM SP. A**

(Plate 5, Figures 19, 20)

Diagnosis. – Colony phaceloid, branching covered thick rugae epitheca. Corallites sub-circular to oval shape. At least two orders of beaded septa within calice.

Material. – A single silicified colony from the Cornwallis Limestone Keku Strait, southeast Alaska MI 0099 (M1911).

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Description. – Colony phaceloid, branching with five distinct buds, covered by thick rugae epitheca. Corallites sub-circular to oval shaped. Septa free, beaded or incomplete
throughout calice extending toward calical center and do not form columella, replaced by pyrite, poorly preserved with two orders recognizable.

Discussion. – We place this species in genus *Stylophyllum* Reuss after the emended diagnosis of the genus put forth by Roniewicz (1989, p. 117). Our specimen exhibits phaceloid branching pattern with free and incompletely joined septa, which are characteristic of this particular genus and therefore warrant its acceptance. Furthermore, this specimen resembles *Stylophyllum pygmaeum* Frech illustrated in Roniewicz (1989, Pl. 36, fig. 9; Pl. 38, fig. 6) in that it is phaceloid (budding marginally) with irregularly developed septa (almost beaded toward the central axis) and a thick, folded (rugae) epitheca. However, we cannot identify this specimen as *S. pygmaeum* Frech specifically because colony size of our sample is much larger, thus warranting another species. Therefore, we consider our specimen as a variety major. However, since we were only able to recover one example, with poorly preserved septal structure, this identification should be considered tentative until more material can be recovered for study.

Occurrence. – Lower Norian from Keku Strait, southeast Alaska.

Genus MEANDROSTYLIS Frech, 1890

Type species. – *Stylophyllum (Meandrostylis) irregulare* FRECH, 1890

**MAEANDROSTYLIS GRANDISEPTUS** Stanley and Whalen, 1989

(Plate 6, Figures 1-3)

*Coccophylum* sp. MONTANARO GALLITELLI et al., 1979, Pl. 3, figs. 7, 8.
Maeandrostylis grandiseptus STANLEY AND WHALEN, 1989, figs. 6.9, 7.2, 7.7, 7.13

Material. – Two specimens from the Cornwallis Limestone Keku Strait, southeast Alaska MI 0099 (M1911).

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Description. – Colony columnar, multi-serial. Corallites cerioid, broad polygonal with regular spaced, deep calices. Septa synapticular, moderately well preserved to four orders extend to calical center, do not form columella. S1 and S2 best preserved, extend ½ to ¾ distance to central axis. S3 observed along wall; S4 (rare) not well defined.

Discussion. – Type material illustrated and described by Stanley and Whalen (1989, Figs. 6.9, 7.2, 7.7, 7.13) match well with material from Keku Strait (MI 0099) particularly with respect to irregularly growing corallum, exceptionally large calices and lack of columella. Corallite diameters in our specimens, average 6-8 mm with septa ranging 26-39, which are on the higher end for this species, nevertheless still fall into proper range established by Stanley and Whalen (1989).
Occurrence. – Lower Norian from Keku Strait, southeast Alaska; Hells Canyon, Oregon.

Genus ANTHOSTYLIS Roniewicz, 1989

Type species. – Coccophyllum acanthophorum FRECH, 1890

ANTHOSTYLIS ACANTHOPHORA (Frech, 1890)

(Plate 6, Figures 4, 5)

Coccophyllum acanthophorum FRECH, 1890, p. 89, Pl. 20, figs. 4-11

Coccophyllum acanthophorum Frech SQUIRES, 1956, p. 19, figs. 19-21; CUIF, 1973, p. 280, figs. 31, 32; CUIF, 1977, p. 17, Pl. 1, figs. 12, 13, Pl. 2, fig. 5; STANLEY, 1979, Pl. 2, figs. 3, 5-7; SENOWBARI-DARYAN, 1980, p. 40, Pl. 4, fig. 6; STANLEY, 1986, Pl. 3.1, figs. 8, 9

Anthostylis acanthophora (Frech) RONIEWICZ, 1989, p. 133, Pl. 41, figs. 5-7

Material. – Fourteen colony fragments from Lake Cowichan and Tahsis Inlet Vancouver Island, Canada MI 8302, MI 9913.
Description. — Colony fragments lamellate with multi-serial columns protruding. Corallites cerioid, polygonal, well defined by sharp walls. Calices deep without columella. Septa non-confluent preserved to three orders forming a distinct depression around calical center. S1 and S2 equal thickness, slightly longer than S3.

Discussion. — Our specimens are identical to illustrations in Roniewicz (1989, Pl. 41, figs. 6, 7) with matching descriptions as well. This species is considered rare from the North American Cordillera, only being found in Rhaetian localities of southern Wrangellia and Lewiston Idaho. The only other occurrence of *Acanthophora* (Frech) from the western hemisphere is from the Norian Pucará Group, Peru. Limited geographical range for this species helps to support paleogeographic results.

Occurrence. — Rhaetian from Vancouver Island, Canada; Lewiston Idaho; Norian from the Pucará Group, Peru; northern Calcareous Alps.
Genus PINACOPHYLLUM Frech, 1890

Type species. – *Pinacophyllum parallelum* FRECH, 1890

**PINACOPHYLLUM PARVISEPTUM, Squires, 1956**

(Plate 6, Figures 4, 6-8)

*Pinacophyllum parviseptum* SQUIRES, 1956, p. 7, figs. 4-8

*Pinacophyllum (?) parviseptum* Squires MONTANARO GALLITELLI, RUSSO AND FERRARI, 1979, Pl. 1, fig. 1

*Retiophyllia dawsoni* (Clapp and Shimer) STANLEY AND WHALEN, 1989, fig. 7.6

*Pinacophyllum cf. P. parviseptum* Squires STANLEY AND WHALEN, 1989, fig. 7.14

**Material.** – Six specimens from the Chitistone Limestone Wrangell Mountains, southcentral Alaska MI 9934 (M1708).

### Dimensions (in mm)

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Description. – Colonies phaceloid, acutely-branching, surrounded by thick rugae epitheca. Corallites bud extracaliculary with deep calices. Three orders of septa preserved. S1 and S2 most prominent, extend to central axis; S3 shorter visible around periphery.

Discussion. – Squires (1956) originally placed this species within family Astrocoeniidae to which Montanaro Gallitelli et al. (1979) agree; however, this family is no longer valid, therefore Stanley and Whalen (1989) place it into family Pinacophyllidae Vaughan and Wells (1943) without justification. However, Roniewicz (1989, p. 135) informally suggest this species more likely resembles Stylophyllum pygmaeum Frech, due to production of equivalent individuals by bifurcation. Stanley (1994) then follows this informal suggestion by placing genus Pinacophyllum Frech into family Stylophyllidae Frech without justification to the move. As a result, we have followed suit with Roniewicz (1989) and Stanley (1994) by placing genus Pinacophyllum Frech into family Stylophyllidae Frech.

In reviewing the identification of Pinacophyllum cf. P. parviseptum Squires illustrated in Stanley and Whalen (1989, Fig. 7.14), we have concluded this specimen to not show sufficient detail in order to justify a solid identification. This specimen is over silicified and does not give any hint as to the presence of a rugae epitheca or give any corallite detail including arrangement and shape of septa; nor depth of calices.

Stanley and Whalen (1989, Fig. 7.6) also illustrate a specimen identified as Retiophyllia dawsoni (Clapp and Shimer) that highly resembles P. parviseptum Squires
with respect to presence of a thick rugae epitheca, septal arrangement, corallite shape and
diameter and depth of calice. However, a spiral budding pattern within the bifurcation
plane is not present within this specimen which is a distinguishing factor given by
Squires (1956).

Occurrence. – Lower Norian from Wrangell Mountains, southcentral Alaska; Hells
Canyon, Oregon; Rhaetian from Lewiston, Idaho.

**PINACOPHYLLUM SP. A**

(Plate 6, Figures 11, 12, 14, 15)

*Diagnosis.* – Phaceloid, obtusely branching colony surrounded by thick rugae epitheca.
Corallites deep (6mm), three orders septa, subequal thickness preserved.

*Material.* – A single silicified colony fragment from the Chitistone Limestone Wrangell
Mountains, southcentral Alaska MI9934 (M1708).

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**Description.** – Phaceloid, obtusely branching colony fragment surrounded by thick rugae epitheca. Four distinct corallites protrude with deep calices (6mm). Two to three orders of septa, uniform thickness within septal order, preserved within calice. S1 thickest, most pronounced extend ¾ way to axis. S2 thinner, extend ½ length of S1. S3 exist only along wall.

**Discussion.** – This new species highly resembles *P. parviseptum* Squires with its phaceloid integration, thick epithecal wall, deep calices, corallite dimensions and uniform thickness of septa. However, it differs with regard to its obtusely branching corallites. *P. parviseptum* Squires contains corallites that spiral or have alternately budding corallites, which is not characteristic of this fragment.

**Occurrence.** – Lower Norian from the Wrangell Mountains, southcentral Alaska.

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**Family** UNKNOWN

**Genus** RHABDOPHYLLIA Milne-Edwards

**RHABDOPHYLLIA TENUICOSTA** Milne-Edwards and Reuss, 1854

(Plate 6, Figures 16-18)

*Rhabdophyllia tenuicosta* MILNE-EDWARDS AND REUSS, 1854, Pl. 6, fig. 18-21

**Material.** – Three fragments from the Chitistone Limestone Wrangell Mountains, southcentral Alaska MI 9934 (M1708).
**Description.** — Colony phaceloid, bifurcation and trifurcation upon budding, partially covered by thin slightly rugae epitheca, horizontal dissepiments are poorly preserved (rare) and present along stalk. Corallites circular, 1-2 mm deep, taper toward stalk. Three orders of ornamented, pinnular, septa preserved. S1 most pronounced, wedge shaped, reaching ½ radius; S2 extend ¼ radius, thinner than S1; S3 wedge-shaped visible as small projections along wall.

**Discussion.** — Historically this species is not well documented. Our specimens match well with the brief description and illustrations given by Reuss (1854). The genus *Rhabdophyllia* Milne-Edwards has not been mentioned in recent Upper Triassic coral taxonomic revisions and therefore, seems to still be valid. However, we refrain from placing this species into a proper family until further study confirms valid microstructure.

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We further note defining morphological characteristics in common with genera *Retiophyllia* Cuif and *Pinacophyllum* Frech to including bifurcation or trifurcation of corallites upon budding, rugae epitheca partially covering the illustrated specimen septal ornamentation (Pl. 6, figs. 17, 18) appearing wavy or zigzagged. However, due to colony size, this could be a result of over silicification and therefore further study should be conducted. This species could possibly be placed into genus *Retiophyllia* Cuif due to branching pattern and septal ornamentation.

*Occurrence.* – Lower Norian Wrangell Mountains, southcentral Alaska; European localities of Milne-Edwards and Reuss (1854).
Plate 1

Figures 1, 2: *Kompsasteria oligocystis* (Frech, 1890)
1. UMIP 228229 (MI 0099, Keku Strait) – View of entire colony showing regular arrangement of corallites. Scale bar 1 cm.
2. Close up showing septal arrangement and thick corallite wall.

Figures 3, 8: *Gablonzeria major* (Frech, 1890)
3. UMIP 400527 (MI 9947, Vancouver Island) – Colonial view showing laminar growth and distinct corallite walls. Scale bar 1 cm.
8. Enlargement illustrating strongly polygonal calices and well-preserved septal arrangement.

Figures 4, 5: *Gablonzeria profunda* (Reuss, 1854)
4. UMIP 303362 (MI 0099, Keku Strait) – View of colony. Scale bar 1 cm.
5. Close up view showing calices.

Figures 6, 7, 10, 11: *Gablonzeria* sp. A
6. UMIP 400488 (MI 9930, Gravina Island) – Transverse thin section showing polygonal walls and septal arrangement. Scale bar 1 cm.
7. Transverse thin section depicting dissepiments and septal arrangement of corallites.
10. Image of large corallite measuring approximately 10mm in length, with S1 septa clearly meeting along the central axis.
11. Image showing intracalicular budding and formation of new corallite wall with the fusing of S1 septa.
*Same scale bar can be used for figures 6, 7, 10 and 11.*

Figures 9, 12-14: *Distichophyllia norica* (Frech, 1890)
9. UMIP 400182 (MI 0099, Keku Strait) – Lateral view showing multi-generational growth and defined epitheca covering daughter calice. Scale bar 1 cm.
12. Side view with prominent ornamentation along both sides of septal surfaces. Scale bar 1 cm.
13. Calical view. Scale bar 1 cm.
14. Close up of septa measuring 8-10mm with well defined ornamentation aligned in vertical rows along surface.

Figure 17: *Montlivaltia c f. M. Marmorea* Frech, 1890
17. UMIP 400482 (MI 9930, Gravina Island) – Weathered specimen surrounded by conglomerate matrix. Scale bar 1 cm.

Figures 15, 16, 18-20: *Kuhnastraea decussata* (Reuss, 1854)
15. UMIP 221065 (MI 8302, Vancouver Island) – Calical view of figure 16 showing well defined septa.
16. Colony view illustrating large intercorallite space. Scale bar 1 cm.
18. UMIP 400328 (MI 9934, Wrangell Mountains) – Specimen showing laminar growth of colony and many compact corallites along surface. Scale bar 1 cm.
19. Calical view of figure 18 with well-defined inter-corallite space surrounding each corallite.
20. Calical view of specimen in figures 18, 19.

Figures 21, 22: *Kuhnastraea cowichanensis* (Clapp and Shimer, 1911)
21. UMIP 400188 (MI 0099, Keku Strait) – Colonial view. Scale bar 1 cm.
22. Close up image showing well-defined septal arrangement and prominent ornamentation of septa.
Plate 2

Figures 1, 2, 5, 6: *Retiophyllia caespitosa* (Reuss, 1865)
1. UMIP 400321 (MI 9934, Wrangell Mountains) – Lateral view with thick rugae epitheca clearly visible along stalk. Scale bar 1 cm.
2. Calical view showing septal arrangement and ornamentation along septal surfaces. Scale bar 5 mm.
5. Another colony (same UMIP) with trifurcation of corallites and imbedded gastropod. Scale bar 1 cm.
6. Calical view third specimen (same UMIP) showing prominent septal spines. Scale bar 5 mm.

Figures 14, 15: *Retiophyllia oppeli* (Reuss, 1864)
14. UMIP 400324 (MI 9934, Wrangell Mountains) – Lateral view depicting thick rugae epitheca, oval calices and irregular branching. Scale bar 1 cm.
15. Calical view of oval corallite. Scale bar 1 cm.

Figures 16-18: *Retiophyllia dawsoni* (Clapp and Shimer, 1911)
16. UMIP 400655 (MI 8302, Vancouver Island) – Lateral view depicting horizontal, runner-type growth. Scale bar 1 cm.
17. Calical view with moderately-well preserved septa. Scale bar 1 mm.
18. Surface view showing multiple corallites and fused branches. Scale bar 1 cm.

Figures 13, 19, 20: *Retiophyllia robusta* Roniewicz, 1989
13. UMIP 228213 (MI 0099, Keku Strait) – Lateral view showing thick stalk and trifurcation of corallites. Scale bar 1 cm.
19. Surface view illustrating trifurcation and thick epitheca. Scale bar 1 cm.
20. Calical view showing septal arrangement. Scale bar 1 cm.

Figures 21-23, 25, 26, 29, 30: *Retiophyllia sp. A*
21. UMIP 22066 (MI 8302, Vancouver Island) – Lateral view of colony showing acutely branching bush-like appearance. Scale bar 1 cm.
22. Surface view illustrating densely spaced corallites. Scale bar 1 cm.
23. Close up view of corallites with well-preserved septa and no ornamentation or dissepiments.
25. Lateral view of colony with multiple bifurcations along the stalk. Scale bar 1 cm.
26. Close up surface view showing septa.
29. Calical view.
30. Calical view.

Figures 24, 27, 28, 31: *Retiophyllia alfurica* (Wilckens, 1937)
24. UMIP 400526 (MI 9947, Vancouver Island) – Lateral view of colony showing unique snake-like corallite stalks with trumpet-shaped corallites. Scale bar 1 cm.
27. Lateral view of a stalk to another colony fragment (same UMIP). Scale bar 1 cm.
28. Surface view of a third colony (same UMIP) showing regular bifurcation and trifurcation of corallites. Scale bar 1 cm.
31. Calical view of poorly preserved septa with apparent granulation (or ornamentation) along septal surfaces.
Plate 3

Figures 1, 2, 5, 6: *Margarosmilia charlyana* (Frech, 1890)
1. UMIP 400335 (MI 9934, Wrangell Mountains) – Surface view showing sub-phaceloid integration and well defined corallites. Scale bar 1 cm.
2. Lateral view of another specimen (same UMIP) illustrating the thin, rugae epitheca and a fused lower-portion to colony. Scale bar 1 cm.
3. Calical view of figure 1, with well-preserved septal arrangement.
4. Septal view of figures 1 and 5, showing well-preserved ornamentation along both sides of septal surfaces.

3. UMIP 400192 (MI 0099, Keku Strait) – Colony fragment. Scale bar 1 cm.
4. Calical view showing abundant septa and sporadic dissepiments.

Figure 7: *Margarosmilia cf. M. zieteni* (Klipstein, 1843)
7. UMIP 400334 (MI 9934, Wrangell Mountains) – Colony fragment showing sub-phaceloid integration, septal arrangement and ornamentation of septal surfaces. Scale bar 1 cm.

Figures 8, 9: *Distichomeandra austriaca* (Frech, 1890)
8. UMIP 226955 (MI 9913, Vancouver Island) – Surface view of latex mold showing sharp distinct walls and well defined pseudomeandroid corallites. Scale bar 1 cm.
9. Close up of figure 8 with detailed septal arrangement.

Figures 10, 11: *Distichomeandra minor* (Frech, 1890)
10. UMIP 228266 (MI 0099, Keku Strait) – Colony view. Scale bar 1 cm.
11. Colony view.

Figures 12, 13, 16, 17, 19: *Margarastraea klipsteini* Frech, 1890
12. UMIP 22068 (MI 8302, Vancouver Island) – Surface view of meandroid corallites with prominent silica veins protruding from the calical centers. Scale bar 1 cm.
13. Close up of meander with septa reaching central fissure.
17. Surface view of low lying, broad septa extending between two adjacent meanders.
19. View of entire colony. Scale bar 1 cm.

Figures 20, 21, 24, 25: *Margarastraea sp. A*
20. UMIP 400043 (MI 0099, Keku Strait) – View of adult colony surface showing circular budding of corallites with thin rugae epitheca present along inner colony ring. Scale bar 1 cm.
21. Close up of figure 20 showing flabellate calice with well-preserved septa (no ornamentation). Scale bar 1 cm.
24. UMIP 400296 – Surface view of juvenile colony. Scale bar 1 cm.
25. Lateral view of juvenile in figure 24 with rugae epitheca. Scale bar 1 cm.

Figures 22, 23: *Margarastraea cf. M. grandissima* (Smith)
22. UMIP 18066 (MI 8831, Gravina Island) – Poorly preserved fragmented colony. Scale bar 1 cm.
23. Calical view.

Figures 14, 15, 18: *Margarastraea sp. B*
14. UMIP 400360 (MI 9938, Gravina Island) – View of colony showing pseudomeandroid integration and large calical dimensions. Scale bar 1 cm.
15. Calical view with preserved septa and well-defined corallite walls.
18. Calical view with well-defined, wavy septa (no ornamentation). Scale bar 1 cm.
Plate 4

Figures 1, 2, 5, 6: *Astraeomorpha crassisepta* Reuss, 1854
1. UMIP 228358 (MI 0087, Keku Strait) – Lateral view showing characteristic wavy pattern, scale bar is 1 cm.
2. Close up view showing many dissepiments along epitheca. Scale bar 1 cm.
5. UMIP 400546 (MI 9947, Vancouver Island) – Surface view of laminar growing colony. Scale bar 1 cm.
6. Close up view of figure 5, showing shared septa, disorderly arranged corallites and occasional fusing of S2 septa with adjacent S2 septa forming triple-junctions between calices (arrow). X 1

Figures 9, 10: *Astraeomorpha confusa* (Winkler, 1861)
9. UMIP 221066 (MI 8302, Vancouver Island) – Close up view showing regular arrangement of corallites with well-defined columella. X 1
10. Surface view. Scale bar 1 cm.

Figures 4, 8: *Parastraeomorpha similis* Roniewicz, 1989
4. UMIP 221092 (MI 8302, Vancouver Island) – Close up surface view. X 1
8. Surface view. Scale bar 5 mm.

Figures 3, 7: *Chondrocoenia schafhaeutli* (Winkler, 1861)
3. UMIP 400643 (MI 8302, Vancouver Island) – Lateral view showing bulbous almost columnar nature with multi serial corallites regularly spaced. Scale bar 1 cm.
7. Close up showing confluent septa and well-defined, button-like, columella. Scale bar 5 mm.

Figures 11, 12: *Chondrocoenia cf. C. paradoxa* (Melnikova, 1968)
11. UMIP 400525 (MI 9934, Wrangell Mountains) – Fragment showing well-preserved corallites and septal arrangement. Scale bar 1 cm.
12. Close up with synapticular, prominent S1 septa. Scale bar 1 cm.

Figures 13-16, 19, 20: *Pamiroseris meriani* (Stoppani, 1858-1860)
13. UMIP 302898 (MI 0070, Keku Strait) – Surface view of mushroom-shaped colony depicting both juvenile and adult corallites. Scale bar 1 cm.
14. Close up of adult corallites showing shared well-preserved septa. X 1
15. Surface view with three juvenile corallites prior to fusing with adult colony. Scale bar 1 cm.
16. UMIP 400314 (MI 9934, Wrangell Mountains) – Colony fragment. Scale bar 1 cm.
19. Another colony (same UMIP as figure 16) with well-preserved septa. Scale bar 1 cm.
20. Close up view of colony in figure 16. X 1

Figures 17, 18, 22: *Crassistella juvavica* (Frech, 1890)
17. UMIP 228362 (MI 0087, Keku Strait) – Close up view showing septal arrangement and well-defined corallite walls and columella. X 2
18. Mound-shaped colony with compact, cerioid corallites. Scale bar 1 cm.
22. Close up view, scale bar 1 cm.

Figures 23, 24: *Crassistella parvula* (Melnikova, 1982)
23. UMIP 303087 (MI 0099, Keku Strait) – Close up surface view showing densely packed corallites. Scale bar 1 cm.

24. Surface view showing both plate-like and columnar growth forms (columnar growth form in foreground out of focus). Scale bar 1 cm.

Figures 21, 25-27: *Crassistella vancouverensis* (Clapp and Shimer, 1911)

21. UMIP 400137 (MI 0087, Keku Strait) – Lateral view showing laminar growth with silicified bivalves and gastropods attached and in matrix below. Scale bar 1 cm.

25. Surface view illustrating highly variable corallite shape and diameter with deep calices. Scale bar 1 cm.

26. Close up showing confluent septa projecting along wall and large calical depression. Scale bar 1 cm.

27. Surface view. Scale bar 1 cm.
Plate 5

Figures 1, 2: *Ampakabastraea cf. A. nodosa* Cuif, 1976
1. UMIP 400524 (MI 9934, Wrangell Mountains) – Colony fragment with well-preserved corallites. Scale bar 1 cm.
2. Close up view of calice. X 1

Figures 3, 4: *Thamnasteriomorpha frechi* (Volz, 1896)
3. UMIP 400498 (MI 9931, Gravina Island) – Columnar view. Scale bar 1 cm.
4. Surface view with well-preserved calices, septal arrangement and multi serial growth of corallites. Scale bar 1 cm.

Figures 5, 6, 9, 10: *Elysastraea fischeri* Laube, 1865
5. UMIP 400308 (MI 9934, Wrangell Mountains) – Mound shaped colony with irregularly shaped corallites. Scale bar 1 cm.
6. Surface view of another colony (same UMIP) with well-preserved corallites and septa. Scale bar 1 cm.
9. Close up of image in figure 6. X 1
10. Calical view (of specimen in figure 6) showing septal arrangement and possible ornamentation. X 1

Figures 7, 8, 11, 12, 17, 18: *Elysastraea haueri minor* (Vinassa de Regny, 1915)
7. UMIP 400309 (MI 9934, Wrangell Mountains) – Lateral view showing branching, multi-serial columnar growth. Scale bar 1 cm.
8. Corallite view along stalk displaying well-preserved synapticular septa and pseudo-columella at calical centers. Scale bar 1 cm.
11. Close up of branching colony showing highly variable shape of corallites with sharp, distinct walls. X 1
12. Close up of well preserved corallites. X 1
17. Highly variable corallites with prominent S1 septa and pseudo-columella along the stalk. Scale bar 1 cm.
18. Well preserved corallites and septal arrangement. X 1
*Same scale bar can be used for figures 8, 11, 12, 17 and 18 of this plate.*

Figures 13-16: *Recticostastraea wallowaensis* Stanley and Whalen, 1989
13. UMIP 221125 (MI 8302, Vancouver Island) – View of colony showing linear parallel to subparallel meanders growing in fan-shaped pattern across colony surface. Scale bar 1 cm.
14. Another colony fragment (same UMIP) with well preserved septa. Scale bar 1 cm.
15. Close up of figure 13 showing over silicified septa. Scale bar 1 cm.
16. Close up of figure 14 with well-preserved septa and linear arrangement of connected calices. X 1

Figures 19, 20: *Stylophyllum sp. A*
19. UMIP 228226 (MI 0099, Keku Strait) – Lateral view illustrating thick rugae epitheca and irregular branching pattern. Scale bar 1 cm.
20. Calical view showing beaded, incompletely joined septa. Scale bar 1 cm.
Plate 6

Figures 1-3: *Maeandrostylis grandiseptus* Stanley and Whalen, 1989
1. UMIP 228272 (MI 0099, Keku Strait) – Multi-serial colony fragment. Scale bar 1 cm.
2. Calical view showing septal arrangement. X 1
3. Close up of colonial view showing large corallites with deep calical depressions and synapticular septa. Scale bar 1 cm

Figures 4, 5: *Anthostylis acanthophora* (Frech, 1890)
4. UMIP 400716 (MI 8302, Vancouver Island) – Surface view of colony. Scale bar 1 cm.
5. Image showing multi serial columnar growth and regularly spaced corallites with characteristic deep calices. Scale bar 5 mm.

Figures 6, 7, 10, 12: *Pinacophyllum parviseptum* Squires, 1956
6. UMIP 400330 (MI 9934, Wrangell Mountains) – Lateral view with thick rugae epitheca. Scale bar 1 cm.
7. Lateral view with thick rugae epitheca. Scale bar 1 cm.
10. Lateral view showing trifurcation of corallites upon budding. Scale bar 1 cm.
12. Calical view showing septal arrangement. Scale bar 5 mm.

Figures 8, 9, 11: *Pinacophyllum sp. A*
8. UMIP 400337 (MI 9934, Wrangell Mountains) – Calical view showing septal arrangement and deep calical depression. Scale bar 5 mm.
9. Lateral view illustrating thick rugae epitheca and obtusely branching corallites. Scale bar 1 cm.
11. Top view showing septal arrangement of two corallites. Scale bar 1 cm.

13. UMIP 400303 (MI 9934, Wrangell Mountains) – Lateral view with thin epitheca exposed along the upper portion of the stalk. Scale bar 1 cm.
14. Calical view showing septal arrangement and ornamentation of septal surfaces. Scale bar 5 mm.
15. Top view showing trifurcation of corallites. Scale bar 1 cm.
Chapter VI: Results for Associated Coral Faunas

(I) Biofacies and Lithofacies Comparisons

Several biofacies and lithofacies are recorded for the first time from the Upper Triassic stratigraphy along the shores of Keku Strait and Gravina Island, SE Alaska (Alexander terrane). Biostrome reef-like deposits are recognized from southern Alexander terrane (Gravina Island) existing in situ (north of Nelson Cove) and as olistolith boulders resting in deeper water calcareous shales (Nehenta Bay). Clear nutrient-poor water is needed to support a coral-rich biostrome reef development of this magnitude. Furthermore, the immense colony size, intergrown nature of corals with other organisms, absence of significant filter and detritus feeding organisms and structured growth of coral colonies argue for zooxanthellate symbiosis. Therefore, during Upper Triassic Lower Norian time, the southern Alexander terrane (Gravina Island) represented the deposition along the fore-reef zone of a small fringing reef where warm, clear-water currents provided a relatively nutrient-free environment with low volcanism and sedimentation rates enabling unaltered structured reef growth.

In contrast coral colonies of central Alexander terrane (Keku Strait) and northern Wrangellia (Wrangell Mountains) do not show structured growth, are smaller in size, and grow separately rather than intergrown. Fossiliferous deposits from this area also contain many types of filter and detritus feeding organisms such as bivalves, gastropods, annelid worm tubes, algae encrusted corals, oncolites, crinoids and echinoderms that indicate nutrient-rich, cloudy water typical of most lagoon environments.

Southern Wrangellia (Lake Cowichan) contains three distinct biofacies (Stanley, 1989) indicating variable environments of deposition during Upper Triassic time. Coral-
rich biofacies including *in situ* branching corals and flat encrusting corals indicate patch reef buildups occurring below the intertidal zone; whereas, highly fragmented bivalves represent deposition along the shallow water beach zone. Biofacies did not contain many detritus and filter feeding organisms such as echinoderms, gastropods, crinoids, algal mats or oncolites which together indicate cloudy nutrient-rich water in a lagoon setting. However, the presence of wood within the *in situ* branching coral biofacies signifies a close proximity to land.

(II) Taxonomic

Four hundred and thirty eight specimens of coral were identified from twelve localities within the Alexander terrane and Wrangellia (Table 2). Twenty-six species were identified from eight localities (five localities from Keku Strait, three from Gravina Island) within the Alexander terrane. From the Alexander terrane, nineteen species were not previously recognized as occurring whereas seven have been recorded by other workers (Appendix A). Combined Wrangellia yielded thirty-three species of coral from four principle localities (one from northern Wrangellia, Wrangell Mountains and three from southern Wrangellia, Vancouver Island). Nineteen species were previously unrecognized in comparison to fourteen already documented species from this terrane. Six new species were identified from both the Alexander terrane and Wrangellia. Two new species from genus *Margarastrea* Frech, and one apiece from genera *Gablonzeria* Cuif, *Pinacophyllum* Frech, *Retiophyllia* Cuif, and *Stylophyllum* Reuss.

(II) Probabilistic Similarity RCSI

Results from running the Raup and Crick (1979) probabilistic faunal similarity index (RCSI) for localities within the Alexander and Wrangellia terranes are presented in
Table 3A and summarized in Table 3B. Overall similarity between two localities is numerically measured based on the amount of shared fauna between two selected areas. Significantly similar localities include (1) Tahsis with Lake Cowichan and Cornwallis Peninsula East, (2) Pender Point with Lake Cowichan and Gil Harbor, (3) Green Butte with Southwest of Kousk, (4) Nelson Cove with Gil Harbor and Phocena Bay, (5) Phocena Bay with Gil Harbor, (6) Nehenta Bay with Big Spruce, (7) Cornwallis Peninsula with Southwest of Kousk, Gil Harbor and Flounder Cove, (8) Big Spruce with Gil Harbor, and (9) Southwest of Kousk with Flounder Cove and Gil Harbor.

Results comparing the Alexander terrane, northern Wrangellia, southern Wrangellia, the Wallowa terrane and Peru are presented in Table 4A and summarized in Table 4B. Results indicate significantly dissimilar faunal pairs include (1) Peru with the Wallowa terrane and the (2) Alexander with the Wallowa, northern Wrangellia and southern Wrangellia. The only significantly similar faunal pair observed from this analysis existed between Peru and southern Wrangellia.

(III) Parsimony analysis of endemicity (PAE)

PAE was performed using the Dollo optimization and Heuristic (NNI) Algorithm (Rosen, 1992, Yarnell 2000). From the analysis, two most parsimonious phylogenetic trees of length 127 were first produced from data pertinent to localities of the Alexander terrane and Wrangellia as well as one most parsimonious phylogenetic tree of length 103 from the lumped Pucará Group in Peru, Alexander terrane, northern Wrangellia, southern Wrangellia and Wallowa terrane.
Table 3A - RCSI analysis matrix for Alexander and Wrangellia terrane localities, depicting faunal similarity based on species level identifications of coral; locality symbols identified in Table 2.

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<th>FC</th>
<th>GH</th>
<th>SWK</th>
<th>BS</th>
<th>CPE</th>
<th>NB</th>
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<th>GB</th>
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+++ = similarity ≈ 96% (greatly significant)  --- = dissimilarity ≈ 4% (greatly significant)
++ = similarity ≈ 87% (significant)  -- = dissimilarity ≈ 14% (significant)
+ = similarity ≈ 74%
* Scale adapted from Yamell (2000)

Table 3B - Simplified RCSI results of Table 3A showing most significant values.
Table 4A – RCSI analysis matrix showing species level faunal similarity in corals of the Alexander, Wrangellia, Wallowa terranes as well as localities from cratonic Peru. Terrane abbreviations given in Table 2.

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<th>NWR</th>
<th>WA</th>
<th>PU</th>
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</table>

+++ = similarity ≈ 96% (greatly significant) — = dissimilarity ≈ 4% (greatly significant)
++ = similarity ≈ 87% (significant)          = dissimilarity ≈ 14% (significant)
+  = similarity ≈ 74%

Table 4B – Simplified RCSI matrix from data compiled in Table 4A with most significant values indicated by symbol. Terrane abbreviations given in Table 2.
Figure 27 shows the majority-rule consensus tree for locality data from the Alexander terrane and Wrangellia, chosen based on geographic position. Groupings of like (sister) areas are as follows: (1) Pender Point together with Tahsis are sister localities that group with Lake Cowichan to form an individual branch, (2) Phocena Bay and Cornwallis Peninsula East are sister localities that group with sister areas of Gil Harbor and Southwest of Kousk distantly grouping with Nelson Cove to make another branch that stems into Big Spruce and Nehenta Bay sister couplet, (4) coral assemblages from Green Butte and Flounder Cove form individual branches indicating no faunal relationship with any other locality.

PAE was then performed on lumped terrane and Peru data, with same settings as mentioned above. Analysis generated a single majority-rule consensus most parsimonious tree of length 103 (Figure 28). Three definite groupings are indicated: (1) the Pucará Group in Peru and southern Wrangellia are sister areas forming a distant branch (similarity) with (2) northern Wrangellia and Wallowa sister areas; (3) the Alexander terrane coral fauna forms a separate branch indicating no faunal relationship.
**Figure 27** – Results from PAE Phylogram depicting majority-rule consensus of the second of two most parsimonious trees with length 127. Diagram shows faunal similarity at the species level in corals from localities of both the Alexander terrane and Wrangellia. Locality abbreviations given in Table 2.
Figure 28 – PAE Phylogram showing majority-rule consensus of one most parsimonious tree length 103. Diagram shows faunal similarity at species level in corals of established terrane localities. Terrane abbreviations given in Table 2.
Chapter VII: Discussion

(I) Preservation

Quality of preservation in recovered fossils limits accurate identification and associated paleobiogeographic designations. Modern schemes of coral identification involving Upper Triassic upper-level (family and genus) coral taxonomy and resulting revision of Norian-Rhaetian taxa have been proposed by Cuif (1965 – 1976) and Roniewicz (1989). Within the scheme presented by Roniewicz, corals are grouped into higher taxa by differences in the microstructural arrangement of their aragonitic skeletons. Applying this scheme to North American coral faunas is difficult owing to the fact that faunas of this study have undergone some degree of replacement by silica, calcite or other minerals. Once corals have undergone mineralogical replacement, their original delicate microstructure is obliterated, thus rendering microstructural classification impossible. In order to cope with this difficulty, North American Upper Triassic shallow-water marine faunas have largely been identified based on traditional morphological comparisons originally made by Frech (1890) and Volz (1896) which Roniewicz (1989) has summarized and updated.

(A) Replacement by Silica:

Variable silicification can increase or decrease the quantity and quality of preserved fossils recovered from etched limestone blocks. This consequently destroys morphology and subtle structure, vital for proper species identification. Within silicified corals, over-silicification can (1) destroy detailed corallite walls, (2) lump together thinly bladed septa destroying their delicate arrangement, (3) produce an entirely diagenetic pseudo-columella mimicking essential characteristics of the species and (4) obliterate
minute ornamentation along septal surfaces (Figure 29A). Under-silicification of a coral colony usually results in an extremely thin and brittle skeleton only having recognizable colony and corallite shape without diagnostic features such as septa, septal arrangement, dissepiments or columella (Figure 29B). When etching limestone blocks that contain under-silicified fauna, care should be taken by using an acetone-based hardener such as Alvar, Butvar, or Vinac; Alvar was used in this study.

(B) Replacement by Calcite:

Non-silicified corals show distinct taxonomic advantages and disadvantages for study. The majority of non-silicified corals have undergone replacement by calcite; however, occasionally the original aragonite is still present. Thus etching in acid would obliterate the entire colony. In this type of preservation most three-dimensional colony shapes cannot be determined or need to be inferred from thin sections. However, this type of preservation may be advantageous when looking at thin sections of corallites. Thin and polished sections may reveal (1) more detailed morphological differences, (2) minute microstructure including trabecular linkages and septal ornamentation (spines), (3) vesicles along the epitheca and (4) thickness of septa. The distinct advantages of calcite preservation may result in positive upper-level taxonomic identification using the modern scheme set forth by Cuif (1965 – 1976), Beauvais (1980) and Roniewicz (1989).
Figure 29 – Examples of A) Over-silicification in *Kuhnastraea cowichanensis* (Clapp and Shimer) holotype specimen, note accretion of silica between corallite walls creating illusion of a thick, shared wall between adjacent corallites. B) Under-silicification of *Crassistella vancouverensis* (Clapp and Shimer) type specimen, showing basic corallite shape without sepal ornamentation and minimal preservation of septa.
(II) Statistics

RCSI and PAUP analyses show similar information in two different ways. RCSI assigns numerical values illustrating the level of similarity between two geographic areas, whereas PAUP helps to visually depict potential linkages in the same geographically defined areas. When two regions or areas are found to be significantly similar, they are inherently assumed to be geographically close to one another. However, statistical analyses carry certain potential error that should be taken into account when determining geographical closeness (see Chapter I part VII). Both RCSI and PAUP compare presence (indicated by a “1”) and absence (indicated by a “0”) data and therefore do not take into account similar environmental conditions that may indicate similarity. Two geographically separate coral faunas may exist under the same environmental conditions (i.e. water temp, depth, amount of sunlight, nutrient level, and similar water current) which would produce two statistically similar coral faunas even though they may be geographically separate. Therefore, statistical tests such as RCSI and PAUP should be utilized in conjunction with other analyses (such as paleomagnetic, geochemical, lithologic and stratigraphic comparisons) to get an accurate sense of terrane paleogeography.

RCSI analysis indicates that localities within the Alexander terrane are statistically similar to each other and could be grouped together for terrane analysis. Likewise, localities from southern Wrangellia are also found to be statistically similar and could be grouped together. Consequently, the locality from northern Wrangellia has statistically dissimilar Upper Triassic coral fauna to both Lake Cowichan and Tahsis Inlet (southern Wrangellia), and has only a 25% correlation with Pender Point (southern
Wrangellia). Having dissimilar fauna between northern and southern Wrangellia is most likely due to age. The locality from northern Wrangellia is Lower Norian and the three localities from southern Wrangellia are Rhaetian. This approximately 16 million year time gap (Gradstein and Ogg, 2004) was most likely long enough for drastic environmental, tectonic and morphological change to occur which would significantly alter the Triassic coral fauna at the genus and species level, thus creating dissimilar faunas along the shores of Wrangellia.

Preferential silicification could not be the sole cause for dissimilar faunas between northern and southern Wrangellia. This is because silicification at Lake Cowichan, Pender Point and Green Butte was immaculate and consistent throughout each deposit. In synopsis, northern and southern Wrangellia could have still been geographically close to one another throughout the Upper Triassic despite having significantly different coal fauna in this study. However, because of this dissimilarity, Wrangellia could not be lumped together for the RCSI and PAUP terrane analysis.

Both the RCSI and PAUP analyses confirm a strong statistical relationship between Peru and southern Wrangellian Upper Triassic coral fauna. Throughout the Triassic, Peru was part of Gondwanaland and remained in the southern hemisphere. Northern Wrangellia (Wrangell Mountains) and southern Wrangellia (Vancouver Island) were found to have low lying paleolatitudes during the Triassic time period (Hillhouose, 1977, Irving and Yole, 1972). Therefore, it seems reasonable to assume a southern hemisphere paleogeographic position for southern Wrangellia during the Upper Triassic.

Newton (1983) obtained a very strong statistical relationship between the Alexander terrane bivalve fauna from Keku Strait and Peru. However, RCSI and PAUP
analysis on coral data does not confirm this relationship. An RCSI value of only 22.5% was obtained from this study and PAUP analysis placed the Alexander terrane on a completely different phylogenetic branch than any other terrane. This could indicate that during the Upper Triassic, the Alexander terrane and Peru were far enough away from each other that larvae from associated coral faunas could not be shared, whereas bivalve larvae were able to settle on both terranes. Throughout the analysis, the Alexander terrane remained statistically dissimilar to other terranes (RCIS) and created a separate phylogenetic branch within the PAUP analysis, suggesting corals from this terrane were not likely shared with these other terranes.

PAUP analysis indicates northern Wrangellia and Wallowa terranes likely shared Upper Triassic coral fauna during the Upper Triassic. However, RCSI only reveals a 46.5% similarity between the two terranes. PAUP analysis agrees with preliminary Upper Triassic gastropod data from Dr. Robert Blodgett (personal communication, 2005) and Upper Triassic bivalve data from Newton (1983) suggesting strong correlation between northern Wrangellia and Wallowa terrane.

Statistical results pertaining to Upper Triassic coral data for both northern and southern Wrangellia and the Alexander terrane differ to preliminary analysis by Yamell (2000). Her analysis, suggests (1) Wrangellia and Alexander terrane are statistically similar to each other at 88% and (2) the Wallowa and Alexander terranes are statistically dissimilar at 11%. Differences in these two analyses are most likely the result of having a larger sample size with many more localities, using etching techniques to enhance results, and updating the previously known coral taxonomy from these two terranes.
Chapter VIII: Conclusions

A variety of laboratory and field methods were discussed in this thesis. Laboratory work focused on improvements to previously known dissolution techniques by using acetic acid accompanied by an acetone based hardener to etch limestone blocks and retrieve valuable fossils instead of HCl. This modification greatly improved the quality of silicified fossils recovered from each locality thus increasing the ability for positive identification aiding paleobiogeographic analysis.

Fieldwork from Gravina Island yielded a new measured section of the Nehenta Formation at Bostwick Inlet. This measured section is vital for biofacies correlation and stratigraphy of the Alexander terrane. Fieldwork confirmed one small-scale reef or biostrome as well as olistolith boulders which indicate warm, calm, clear water with lots of sunlight and low nutrient levels for the southern Alexander terrane (Gravina Island). Localities from Wrangellia (northern and southern) and Keku Strait (central Alexander terrane) contained no reef-like buildups. Corals from these areas grew as individual colonies along with a wealth of filter and deposit feeding organisms indicating warm, nutrient rich, cloudy water. These findings further test the theory that terrane localities within the North American Cordillera did not support large reef buildups during the Upper Triassic in comparison to the Tethys Sea.

Systematic identification of 458 Upper Triassic corals took place from twelve principle localities within the Alexander terrane and Wrangellia. Nineteen previously unrecognized species were found within combined Wrangellia and the Alexander terrane; six of which are new from this study. The Flounder cove locality in the Alexander terrane and Green Butte in northern Wrangellia contained the overall highest diversity of
Upper Triassic faunal assemblages. Both of these two localities contained mixed Carnian/
Norian coral fauna. This is important because Upper Triassic coral faunas throughout
the world do not typically mix between these time periods and could therefore be vital
when looking at the Carnian/Norian extinction event (Flugle, 2002) and discussing
possible holdover or refugia faunas.

All twelve localities described in this thesis contain fossilized fauna that have
been preserved with variable degrees of silicification. Gil Harbor (Alexander Terrane),
Flounder Cove (Alexander Terrane), Lake Cowichan (southern Wrangellia) and Green
Butte (northern Wrangellia) posed the best overall silicification of Upper Triassic fauna.
Fossil corals from these localities were preserved with minute details along septal
surfaces as well as intricate colony growth form and interactions between organisms
(Figure 8).

Paleobiogeographic analysis suggests the Alexander terrane does not have Upper
Triassic coral fauna similar to northern or southern Wrangellia, the Wallowa terrane and
even Peru. Likewise, Upper Triassic corals from northern and southern Wrangellia are
found to be statistically dissimilar to each other as well. However, this is most likely due
to a significant time gap (18 my) between strata. Upper Triassic coral fauna from
southern Wrangellia is found to be most similar to that of the Pucará group in Peru,
whereas the fauna from northern Wrangellia was only found to be comparable to the
Wallowa terrane when analyzed using PAUP analysis.

Given these results, it can be concluded that both the Alexander terrane and
Wrangellia were situated somewhere within the warm, tropical latitudes of the
Panthalassan Ocean during Upper Triassic (Norian – Rhaetian) time period (indicated by
The presence of diverse coral faunas. However, the Alexander terrane developed separately, having Upper Triassic corals that were not similar with any other aforementioned terrane. Coral data generally agrees with previous paleomagnetic analysis indicating these two terranes were not situated in close proximity to each other (Alexander terrane having a more northern paleolatitude), containing few overlapping species (those with planktotrophic larvae, also found within Tethys Sea and other terranes). Southern Wrangellia most-likely had a low-lying paleolatitude somewhere near Peru (as indicated by an extremely high similarity index coefficient). Northern Wrangellia, in turn, was situated in close proximity to the Wallowa terrane. However, age correlation differences between northern and southern Wrangellian coral faunas inhibit proper paleogeographic positioning between these two sub-terranes.

The presence of evaporite minerals and absence of fossilized wood (and other flora) within northern Wrangellia further indicate the northern Wrangellia / Wallowa terrane couplet were positioned within a warm, arid, dry environment during this time period. Localities within the Alexander terrane and southern Wrangellia contained an abundance of fossilized wood indicating a tropical, humid environment that was in close proximity to land. Therefore, it can be said from this analysis that during the Upper Triassic time period, the Alexander terrane and Wrangellia contained statistically dissimilar coral faunas. Thus were most likely not yet amalgamated within the Panthalassan Ocean.


