NEW INVESTIGATIONS ON EAGLENEST MOUNTAIN, NORTHERN QUESNEL TERRANE: AN UPPER TRIASSIC REEF FACIES IN THE TAKLA GROUP, CENTRAL BRITISH COLUMBIA (93N/11E)

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INTRODUCTION

A number of carbonate deposits and reefs are known in the Cordillera. Those in Canada are described by Geldsetzer and James (1988). The few examples from the early Mesozoic occur exclusively in Cordilleran displaced terranes. Most show variation in thickness, fossils and facies content. Most of these reef-like carbonate bodies are characterized by a fauna of corals and sponges. They tend to be small, and most lack the thickness and complexity typical of coeval deposits in Tethyan reefs of Europe and Eurasia (Stanley, 1988b). Only two Upper Triassic reef sequences comparable to those of the Tethys are known in the the Americas. These are the Wallowa Terrane of Oregon (Stanley and Senowbari-Daryan, 1986) and an example from the Yukon in the Stikine Terrane (Reid, 1988; Reid and Tempelman-Kluit, 1987). The Yukon example stands alone as the thickest and best developed Triassic reef complex known among Cordilleran terranes. It also reveals close correspondence of fauna and facies with those of distant reefs in the former Tethys region. An example of a Tethyan-type patch reef is known from Lower Jurassic volcanics in Hazelton Group of British Columbia (Stikine Terrane) described by Stanley and McRoberts (1992) and Stanley and Beauvais (1994). All reef examples occur in displaced terranes. According to Stanley (1988a, 1995) they existed during Permian and Triassic time as fringing volcanic islands in the ancient Pacific Ocean. Since that time they have become accreted to the North American craton, as part of allochthonous terranes.

This paper is a preliminary report on a newly recognized Upper Triassic reef complex investigated during the summer of 1995 in the Takla Group of British Columbia. It lies within Quesnellia, a late Paleozoic - early Mesozoic island arc terrane (Figure 1). The site on Eaglenest Mountain in the Kwanika Creek map area was recognized during the course of geological fieldwork (Bailey *et al.*, 1993) and briefly described by Nelson *et al.* (1993). These authors recognized the reefal nature of the massive limestone exposed at this site. It occurs within an augite-phyric, mainly pyroclastic basalt sequence near the assumed top of the Upper Triassic Plughat Mountain succession, which is unconformably overlain by Lower Jurassic volcanic rocks. The Plughat Mountain succession represents a primitive intra-oceanic arc. Its uppermost unit in the Kwanika Creek area is a bright red amygdaloidal to scoreaceous basalt, which overlies darker green pyroclastic and pillow basalt. This stratigraphy suggests that the sequence shallowed upwards and became shallow marine to possibly subaerial by the end of the Triassic.

The Eaglenest site is significant because it provides the first paleontologic and sedimentologic glimpse of carbonate reef rocks within Quesnellia. Data derived from this reef undoubtedly will prove significant by supplying infor-

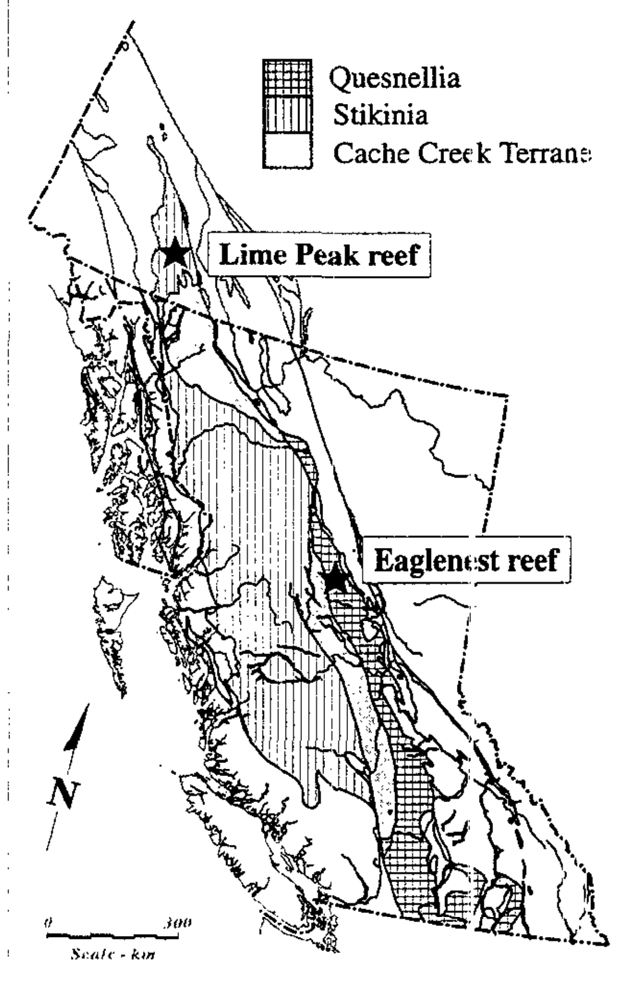

Figure 1. Location of the Eaglenest reef within the Canadian Cordillera.

mation to assess paleogeography and evolution of early Mesozoic reefs and by providing a basis for comparison with the reefs of other terranes. The massive limestone at Eaglenest compares well with the Yukon example previously mentioned. It also has a rich reef fauna, including biostratigraphic fossils which allow dating of the limestone. The Eaglenest complex of reef and reef-associated limestone, its fauna and carbonate lithofacies are currently the subjects of a detailed investigation.

DESCRIPTION OF THE REEF

Seven rock types (gross lithofacies) were recognized and mapped within the kilometre-wide cliff face at Eaglenest Mountain (Photo 1, Figure 2). The exposure is dominated by limestone lithofacies but volcaniclastic and mixed limestone-volcaniclastic units are also present. The limestone is surrounded by a much thicker volcanic sequence, the Plughat Mountain succession. The thickest exposure of unbroken massive to thick-bedded limestone is at the south end of the outcrop. Here carbonate rocks are juxtaposed against volcaniclastics, with as much as 200 metres of limestone exposed (Photo 1, Figure 2). It is difficult to measure a single representative section because the limestone intervals lie at different attitudes, setting off certain parts of the section from others. These bedded limestone units thicken and thin and are commonly interbedded with adjacent volcaniclastic rocks. At least four isolated blocks are present in the exposed cliff face; they display various bedding attitudes relative to the surrounding rock and to each other. Bedding attitudes in the cliff face are also affected by several normal faults. Dips in the limestone are variable, but most are gentle to northeast. On the other hand, the overall contact between the limestone and the surrounding pyroclastic succession dips moderately to the west. Some of the the sharp contacts between volcaniclastic rocks and limestone are fault controlled but most appear to be depositional. The lithofacies recognized during the field investigation are briefly described below.

STRATIGRAPHY AND LITHOFACIES

The light grey carbonate rock types include: 1) *Heterastridium* conglomerate which overlies the massive limestone at several sites, 2) sponge and coral limestone, 3) massive recrystallized limestone, which forms large bedded sections and also blocks, 4) crinoidal limestone and 5) chaotic breccia and conglomerate. As shown in Photo 1 and Figure 2, these carbonate rock types are associated with noncarbonate rock types consisting of: 1) volcanic sandstone and lime-matrix basalt breccia, 2) bedded bioclas-

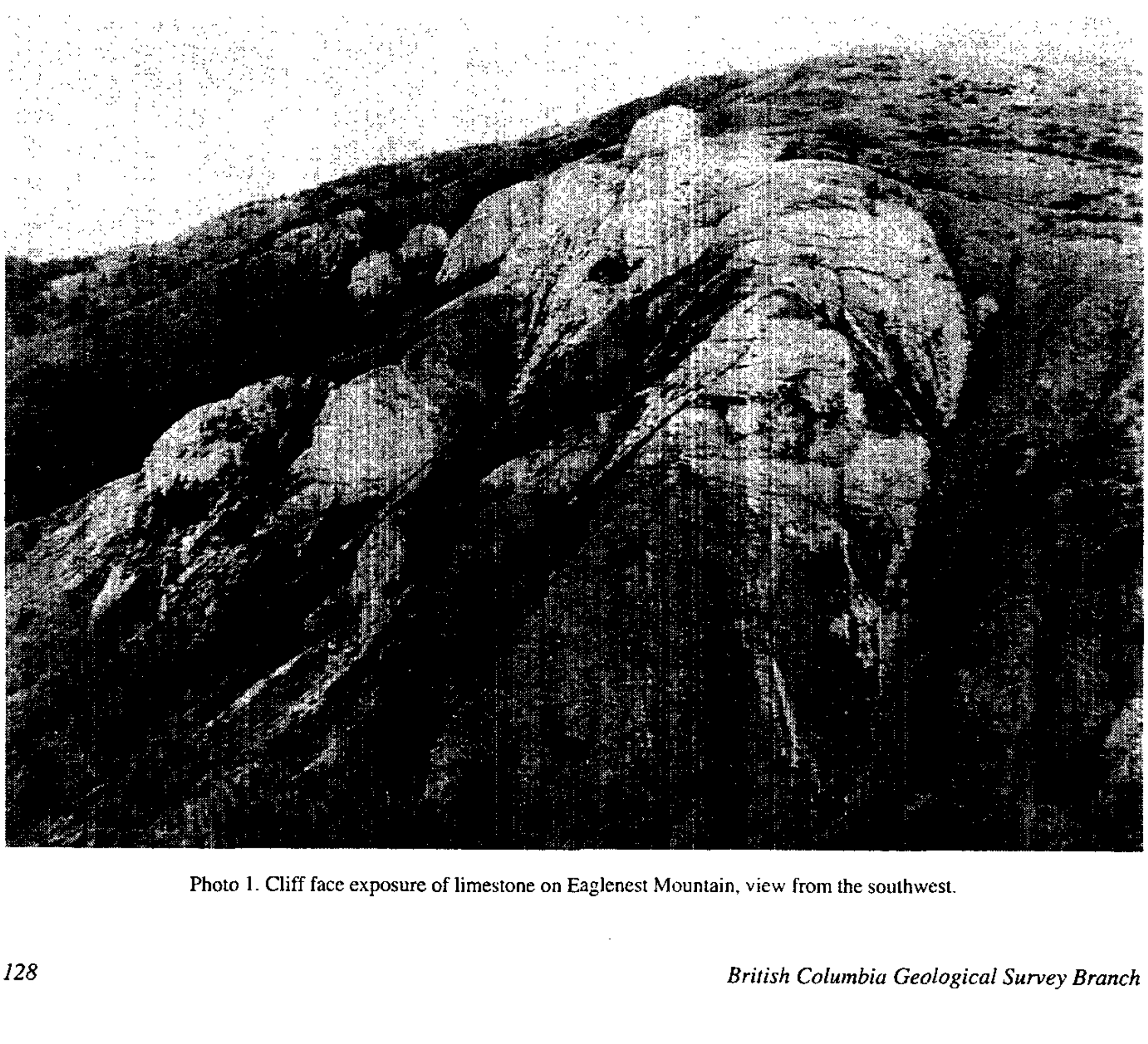

Photo 1. Cliff face exposure of limestone on Eaglenest Mountain, view from the southwest.

tic/volcanic sandstone and 3) augite-phyric agglomerate and lapilli tuff. This report focuses primarily on the carbonate rock types and associated fossils.

HETERASTRIDIUM CONGLOMERATE

The *Heterastridium* conglomerate, at the top of the sequence, is in sharp contact with underlying sponge and coral limestone. This conglomerate ranges in thickness from 8.0 to 10.0 metres and consists almost exclusively of rounded spheres of *Heterastridium conglobatum* 1.5 to 3.0 centimetres in diameter (Photos 2a, 2b). These fossils were deposited in closely packed arrangement in direct contact with each other. *Heterastridium conglobatum* Reuss is a spherical to globular, floating hydrozoan colony which attained global marine distribution during Late Triassic (middle to late Norian) time. For this reason it is a biostratigraphically useful fossil with occurrences in parts of Alaska, western Canada (including the Queen Charlotte Islands) and in western Nevada (Silberling and Tozer, 1968). It is indicative of the upper Norian (Cordilleranus and Amoenum Zones), often occuring with the flat clam *Monotis (Pseudomonotis) subcircularis. Heterastridium* has recently been identified in the Antimonio Terrane of Sonora, Mexico (Stanley *et al.*, 1994).

According to Leo Krystyn (written communication 1995), *Heterastridium* in the former Tethys region ranges from at least as low as uppermost middle Norian to upper Norian. Populations of small individuals (2-3 cm diameter) indicate middle Norian (Alaunian 3/II) while larger sizes indicate higher intervals in the upper Norian. This taxon was extinct before the end of the Triassic as no latest Triassic (Rhaetian) occurrences are known. The diameters

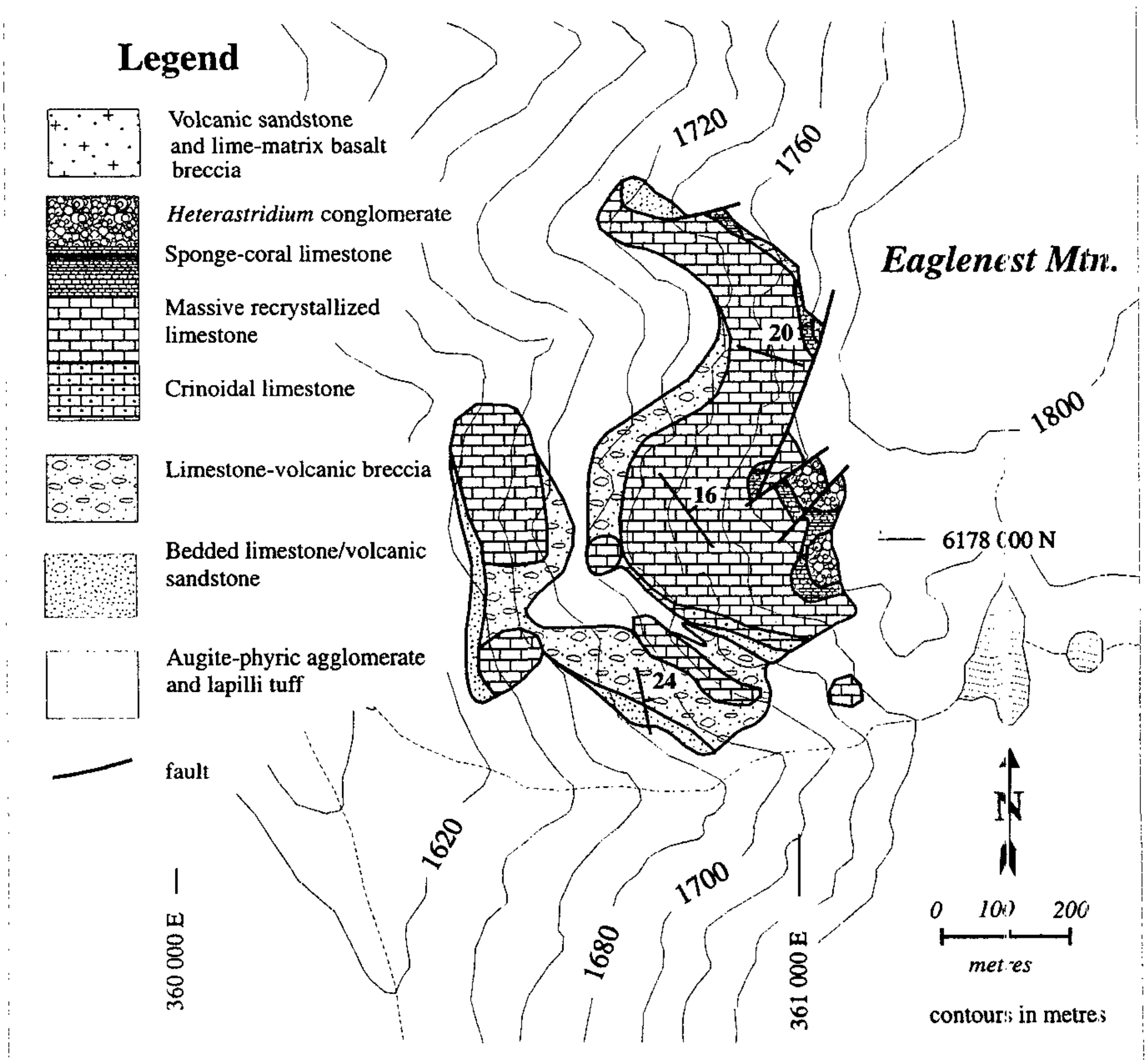

Figure 2. Detailed geologic map of the Eaglenest reef.

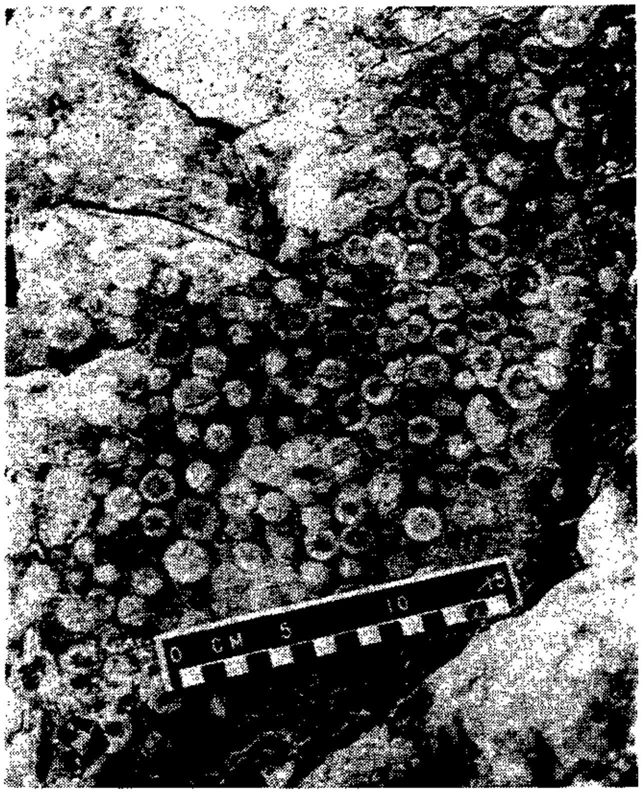

Photo 2a. Outcrop photo of *Heterastridium* conglomerate lithofacies. Note the tightly packed spherical colonies of this floating hydrozoan. Their abundance and the nature of the deposit indicates beaching of thousands of these organisms, or the mass sinking of waterlogged colonies. Scale in centimetres.

Photo 2b. Polished slab of *Heterastridium*, showing the numerous radiating canals of the coenosteum, which were originally filled with air. Most spherical colonies have recrystallized. The void spaces are filled with clear calcite and encrusted by cyanobacteria representing porostomate algae (dark coatings). Scale in centimetres.

found in the Eaglenest indicate middle Norian strata. The voluminous occurrences of *Heterastridium* at Eaglenest are unusual, as these planktonic fossils usually occur fairly dispersed in other North American occurrences and usually indicate deep water. The only other known examples of Heterastridium in concentrations as thick and dense as those at Eaglenest come from the Upper Triassic (Norian) of Karakorum, Timor and New Zealand (Campbell, 1974).

At Eaglenest the basal contact with the Heterastridium conglomerate is unconformable and probably represents a small erosional break. The *Heterastridium* facies appears to fill in local irregularities (probably karst surfaces) on top of the reef limestone. The limestone is also cut by small neptunian? dikes or fractures 10 to 50 centimetres wide. These are infilled with additional reworked? *Heterastridium* but these fissures are filled mostly by coarse-grained, sandy polymict volcaniclastic sediments. The fractures appear to be confined to the top of the reef limestone and do not seem to penetrate very deeply.

SPONGE-CORAL LIMESTONE

This lithofacies outcrops at several sites in the map area (Figure 2) and is estimated to be 10 to 50 metres thick. It lies directly below the *Heterastridium* conglomerate and is gradational into the underlying massive recrystallized limestone. It consists of abundant upright-growing and encrusting sponges, spongio-morphs, disjectoporoids and corals, mostly in life positions. Such organisms, reef builders at other Triassic reef sites in the Yukon and the Tethys, appear to be an important limestone builder in the Eaglenest limestone. Study of these organisms is currently underway at the University of Montana. Large-chambered thalamid sponges (Photo 3) are volumetrically the most abundant elements. They include the genera *Nevadathalamia* and *Cinnabaria* and possibly other sponges which are already known from the Yukon reef locality and also from nonreef localities in the Luning Formation of western Nevada (Senowbari-Daryan and Reid, 1987, Senowbari-Daryan and Stanley, 1992) and the Antimonio Formation of Sonora (Stanley *et al.*, 1994). Small spar-filled cavities are created by shelter porosity. Other cavities appear to be of solutional origin.

Of less volumetric importance in this lithofacies are moderate to large colonial scleractinian corals (Photo 4). These include *Retiophyllia, ?Kuhnastraea, Chondrocoenia*, indeterminate meandroid corals and large tabular colonies of *Pamiroseris*. Also present are irregularly encrusting yet problematic organisms referred to as disjectoporoids and massively encrusting hydrozoans referrable to the genus *Spongiomorpha*. Spongiostromate crusts, attributable to cyanobacteria, are also present within cavities. Microfossils such as foraminifers and algae have yet to be identified and studied in thin section. Bivalves and gastropods are present, but have not been identified. At one site below the *Heterastridium* conglomerate, a prominent bivalve shell bed charac-terizes the top of the sponge-coral limestone; it may indicate a different paleocommunity that succeeded the reef.

Photo 3. Polished specimen of the chambered sponge *Nevadathalamia* sp. from the sponge-coral lithofacies. The matrix is skeletal debris of corals and molluscs. Scale in centimetres.

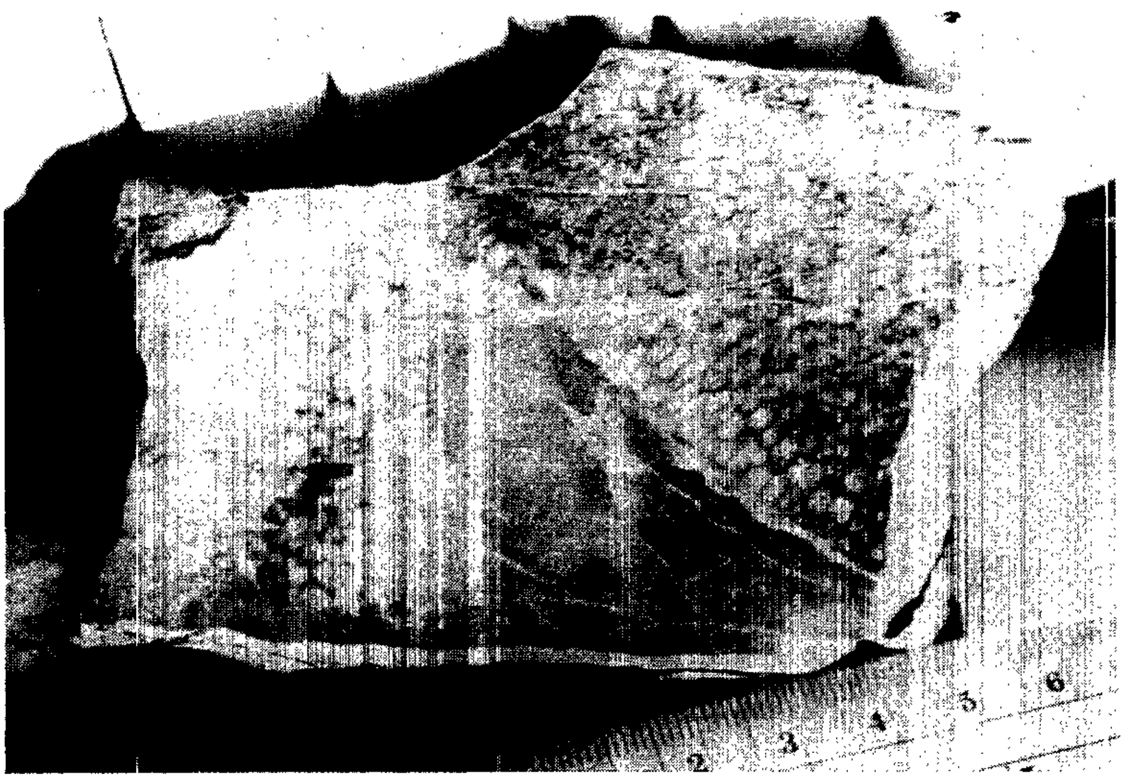

Photo 4. Colonial cerioid coral *Chondrocoenia* sp. Large encrusting colony growing on fine-grained matrix. Sponge-coral lithofacies. Scale in centimetres.

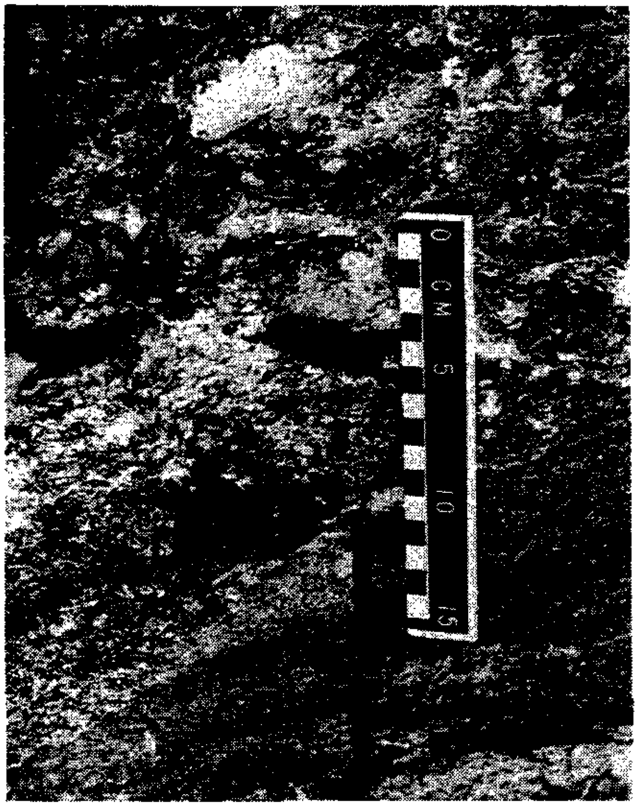

Photo 5. Field photo of crinoidal limestone showing planar and low-angle crossbeds. Scale in centimetres.

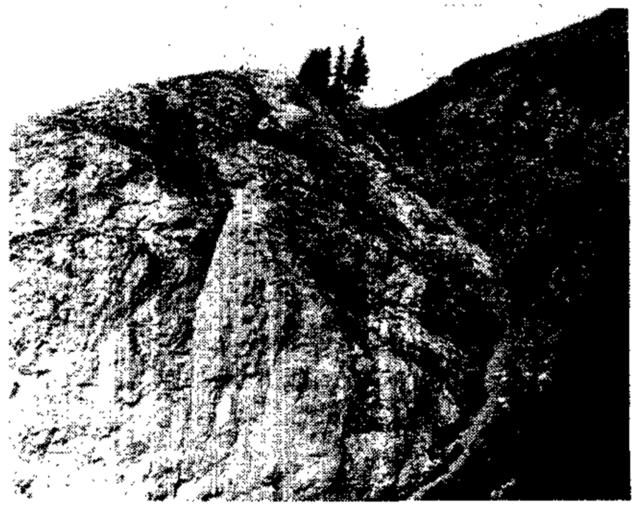
Photo 6. Edge of one of the large blocks of massive recrystallized limestone surrounded by pyroclastic debris and chaotic breccia and conglomerate. The contact is abrupt but unsheared, suggesting that it was emplaced in its matrix by gravity sliding rather than later faulting.


Photo 7. Limestone-volcanic breccia in outcrop, lying above bedded bioclastic/volcanic sandstone (lower left). Outcrop shot shows chaotic breccia composed of large clasts of limestone and volcanic rock up to 4 metres in diameter.

Photo 8. Details of the limestone-volcanic breccia showing clasts of fossils, limestone and volcanic rock fragments. Scale in centimetres.

MASSIVE RECRYSTALLIZED LIMESTONE

Most of the light-coloured limestone in the cliff face displays a recrystallized texture and is massive to thick bedded. Due to the diagenetic effects of the recrystallization, little is revealed of original lithology, texture or biotic constituents. However some breccia-like textures are present, as well as crinoid columnals, bivalves or brachiopods and some vaguely defined branching coral or sponge-like fossils. We suspect that prior to recrystallization this lithofacies may have contained textures and fossils similar to those of the sponge-coral limestone.

CRINOIDAL LIMESTONE

This lithofacies (Photo 5) is an impure limestone with laminations and crossbedding. It is mostly a bioclastic limestone characterized by abundant abraded echinoderm debris, predominantly disarticulated and abraded crinoid ossicles (packstone textures) and molluscan shells. Among the crinoid ossicles are scattered five-sided "*Isocrinus*", incorrectly identified as pentamerid corals in Nelson *et al.* (1993). The limestone contains a large admixture of sand-size volcaniclastic grains. Whole cidaroid echinoid spines, test fragments and much molluscan shell debris are present locally. Rare spiriferid brachiopods were also observed. Whole and abraded coarse-ribbed bivalves (including pectinaceans), and reworked corals, sponges and disjectoporoids are common in the upper portions of this lithofacies. The crinoidal limestone is at least 30 metres thick, but thickness varies considerably across the exposed cliff face. Strata are thin to medium bedded, with irregular contacts producing a nodular appearance. Low-angle crossbedding is visible in weathered outcrops.

LIMESTONE BLOCKS

This lithofacies consists of massive to thick-bedded, light-coloured limestone blocks reaching 100 to 200 metres in length. These are enclosed in a chaotic mixture of breccia and conglomerate described below. At least four such blocks were mapped in the lower parts of the cliff face (Photos 1, 6, Figure 2). The composition of the blocks is pure recrystallized limestone similar to the massive recrystallized limestone lithofacies previously described. Mapping has shown that the large blocks are incorporated within the chaotic breccia and conglomerate described below. Although fossils are difficult to discern due to the recrystallization, typical reef forms of sponges and corals are recognized.

LIMESTONE-VOLCANIC BRECCIA

This lithofacies consists of a chaotic mixture of poorly sorted, angular to subrounded limestone clasts and rounded volcanic rock fragments set in a matrix of lime mud and/or grain-supported carbonate rock (Photo 7). Individual limestone clasts of various orientations range in size from 2 centimetres to the outcrop-sized blocks described in the previous section. The generally smaller, dark-coloured volcaniclasts are amygdaloidal and augite-phyric basalt (Photos 7, 8). Most limestone clasts are slightly recrystallized. Some contain large coral colonies of *Retiophyllia* as well as sponges and other reef fossils similar to those found in the sponge-coral facies (see above). The chaotic breccia and conglomerate unit occurs within the augite-phyric agglomerate and lapilli tuff beds and is in contact with the crinoidal limestone and the massive recrystallized limestone (Figure 2).

Volcanic sandstone and lime-matrix basalt breccia is found only in one small area in the northeast part of the cliff exposure (Figure 2). This lithology may represent either an incursion of surrounding sediments into the reef or the filling of fissures in the reef. The augite-phyric agglomerate and lapilli tuff surrounding the reef limestone represent volcanic depositional patterns within the inter-arc basin in which the reef developed. The volcanic processes were probably occurring simultaneously with the deposition of the organic reef limestone.

INTERPRETATIONS

Several of the lithofacies mapped at Eaglenest Mountain - the sponge-coral facies, the massive recrystallized limestone and the crinoid facies - are interpreted to represent part of an Upper Triassic reef complex. These lithofacies are comparable to other Triassic reef sequences, especially those in Oregon and the Yukon. The reef organisms also appear similar to those occurring in other reef complexes and in some nonreef associations such as in western Nevada and Sonora, Mexico but detailed taxonomic study is not yet complete enough to allow meaningful comparisons. Paleontological study currently underway is expected to be completed soon and should yield good comparative data.

We interpret both the sponge-coral facies and the massive recrystallized limestone, comprising the bulk of the carbonate lithofacies, to represent the main reef facies. Further investigations may result in narrower subdivision and recognition of specific environments such as backreef, lagoon etc., but at present, the volumetric abundance of *in situ* framework-building taxa of chambered sponges, corals and other fossils leaves little doubt about a reef origin. The crinoid facies is laterally equivalent and is interpreted to represent a down-slope (forereef) facies.

Eaglenest Mountain is interpreted here as a disrupted reef complex. Unlike reef sequences from some other terranes, the limestone at Eaglenest is disrupted and broken into numerous blocks with variable bedding attitudes relative to each other and to bedding in the surrounding volcaniclastic and volcanic rock lithofacies. At odds with the idea of an *in situ* reef growing on a volcanic edifice (Nelson *et al.*, 1993), we interpret these carbonate rocks to represent an allochthonous series of limestone blocks transported into a deeper water basin or off-shelf (?slope) setting by syndepositional gravity sliding and associated down-slope debris flow. In this interpretation, the limestone bodies now juxtaposed at the Eaglenest site are comparable to olistostromes or olistoliths common on other Triassic island arc settings such as the Eastern Klamath Terrane of California (Eastoe *et al.*, 1987). The blocks were most likely derived from a shallow-water carbonate shelf developing on the fringe of a volcanic island, in an environment of steep constructional slopes and active tectonism. The subrounded to rounded shapes of some limestone and volcaniclasts in the chaotic breccia and conglomerate suggest an episode of recycling and transportation in a shallow shelf setting prior to displacement into deeper water. Subsequent block faulting has slightly modified the original relationships of the limestone.

We base the allochthonous gravity slide hypothesis on the sharp nature of the lower contact of the massive recrystallized limestone with the underlying chaotic breccia and conglomerate - a lithofacies showing classic characteristics of downslope debris flows with small to fairly large size allochthonous blocks (Photos 7, 8). We find that only a few of the observed sharp contacts can be accounted for by faulting. The 200 or more metres of limestone exposed in the cliff face display different inclinations and most likely represent several allochthonous blocks displaced into deeper water by gravity sliding. This would account for the various angles of dip observed in the sequence, the isolated nature of the limestone blocks, the lower contacts of the largest limestone body which rests abruptly on the chaotic breccia and conglomerate lithofacies and the abrupt nature of the contacts between limestone and adjacent volcaniclastic rocks (*e.g.* Photo 6). Olistostromic sliding may have been induced by gravity or triggered by earthquakes in the arc basin. Syndepositional slumping, gravity induced debris flows and general collapse of shelf margins are processes expected within island arc-trench settings. In the case of Eaglenest it appears to have resulted in the disruption and possibly a collapse of a shallow- water, tropical reef.

The *Heterastridium* conglomerate is interpreted to represent a postdepositional event occurring soon after death of the reef and its uplift and karst development, but prior to slumping into deeper water. The irregular contact between the densely packed *Heterastridium* conglomerate and the underlying reef limestone indicate that the original shallow-water reef had been uplifted and subjected to some karst processes. The closely packed *Heterastridium* concentration may represent storm deposits that washed these floating hydrozoan colonies into a shallow water, subtidal (near-shore) environment. Thus interpreted, the *Heterastridium* bank was deposited after waterlogged colonies accumulated in shallow, open shelf water. Comparable accumulations occur in the Hallstätt Beds of Germany and Austria (Zankl, 1969) and in the Norian of New Zealand, where dense *Hetera- stridium* banks are observed (Campbell, 1974). The volcaniclastic fissures filling the top of the limestone most likely represent a subsequent phase which could have coincided with slumping or later faulting.

AGE

Previous conodont collections from the Eaglenest reef complex are broadly Upper Triassic (M. J. Orchard, personal communication to J. Nelson, 1993). The occurrence of the *Heterastridium* conglomerate and the abundance of small-size spherical colonies of *Heterastridium conglobatum* constrain the biostratigraphy to uppermost middle to upper Norian. As we interpret the *Heterastridium* conglomerate lithofacies as a younger post-reef feature of deposition, the underlying reef limestone must be older, probably lower to middle Norian. This age assessment is reasonable considering the similarity of the sponges, corals and other reef organisms with those from lower and middle Norian localities (Senowbari-Daryan and Reid, 1987; Senowbari-Daryan and Stanley, 1992; Stanley *et al.,* 1994). Retrieval of additional conodonts from the Eaglenest rocks could better constrain the age of the reef limestone and associated lithofacies.

CONCLUSIONS

The limestone lithofacies on Eaglenest Mountain represent the remains of an Upper Triassic reef that was populated by sponges, corals and a variety of reef-building and reef-dwelling organisms. It existed within an island arc setting, preserved in the predominantly volcanic Takla Group. This thick limestone reef in the Takla Group suggests that it lay at tropical to subtropical paleolatitudes. We interpret the limestone lithofacies as sedimentologically allochthonous with respect to the surrounding volcaniclastic rocks. The limestone was displaced as a debris flow with large olistoliths, from an original site on a shallow-water shelf into a basin. This occurred after lithification of the reef, uplift, karst development and the deposition of *Heterastridium* conglomerate.

The Eaglenest limestone is one of the few remnant Upper Triassic reefs in the Cordillera that have yielded well preserved fossils. It offers new insights into reef development and reef fauna in Triassic Quesnellia. Ongoing study of its fossils is expected to provide long needed data for reconstruction of paleogeography and comparisons with other displaced terranes in the Cordillera.

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NOTES