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Hydrothermal Seeps and Trilobite Reproduction in the Middle Cambrian: The Burgess Shale High School Research Project Investigates the Mount Stephen Trilobite Beds

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INTRODUCTION

On September 16, 2000 about twenty students, teachers and mentors, under the direction of Dr. Henderson, hiked straight up Mount Stephen to a point about 520 metres above the town site of Field, British Columbia in order to investigate the Mount Stephen trilobite beds. This fossil site was discovered in 1886 by R.G. McConnell of the Geological Survey of Canada and has been visited many times since by tourists and researchers. The students were there 114 years after the discovery to conclude research on the trilobite *Ogygopsis* as part of a Burgess Shale High School Research Project. Since its establishment in 1996, the Burgess Shale High School Research Project has involved students from Canmore, Banff, and Golden and in the past two years from Invermere as well. It is a cooperative project between The Yoho-Burgess Shale Foundation and the Department of Geology and Geophysics at the University of Calgary. This year the students conducted research in order to understand better why the trilobites are so abundant at this site as well as to gain an appreciation of science and the scientific method.

Research methods included the measurement and biometric analysis of about 150 specimens of *Ogygopsis* as well as numerous geological observations around the site. Students and teachers also conducted research in their schools on modern arthropods and hydrothermal vents. Last year a different group of students measured over 190 specimens of *Ogygopsis* and other taxa including *Olenoides*, *Bathyuriscus*, and *Elrathina*. The students took measurements on site and no fossils were removed. The measured parameters included cranidium width and length, cephalon width and length, thorax length, and pygidium length, as well as the number of thoracic and pygidial segments. These data were collected in order to address two possible hypotheses that could explain the

abundance of trilobites at this site: 1. That the trilobites were transported to this site and thus concentrated by sedimentologic processes or 2. That the trilobites lived and/or molted at this site where conditions were favourable for them to occur in abundance. The primary conclusions from last year were that the near uniform mud to silt grain size, the smooth and uniform bedding with only parallel laminations, and the lack of alignment and fragmentation of most trilobite specimens all point to a quiet marine setting with minimal currents and well below fair-weather wave base. The fact that virtually all of the trilobite specimens are adults, that most are molts (82% of *Ogygopsis*) with a minimal number of molt stages indicated, and that they were deposited always in the same orientation (dorsal side up and parallel to bedding), but randomly aligned on bedding surfaces supported the lack of currents and suggested a specialized biocoenosis; one student suggested it was an “ogycoenosis”.

NEW INTERPRETATIONS

The most significant new observation is that the Mt. Stephen site is actually a tilted slab of seafloor in which numerous carbonate mud-mounds stand in relief, exhumed from the surrounding mudstone and siltstone. The onlap of shale around these mounds accounts for the characteristic kite-shape of this deposit as seen from the town-site of Field. Fragments of the carbonate mud-mounds were also recognized in the shale where they deformed the mud laminations indicating that the carbonates stood in relief during deposition of the shale. These carbonate mud-mounds have been interpreted as the result of hydrothermal seeps by Johnston and Collom (1999) and Collom and Johnston (1999) and they suggest that these seeps may have a bearing on the biotic composition and preservation. Our observations and interpretations suggest that numerous features of the “ogycoenosis” may be explained by the proximity of these hydrothermal carbonate mud-mounds. These hydrothermal fluids were probably associated with rejuvenated faulting along the Kicking Horse Rim, which is present near the study location. Renewed tectonic activity along the Kicking Horse Rim may have resulted in hydrothermal vents along its length, whereby seawater percolating down through fissures became superheated and rose again as mineral-enriched geysers on the sea floor.

Richard Fortey’s book “Trilobite” (2000) provides a valuable comparison. He indicates that 500 million year old olenid trilobites from the Upper Cambrian were the first animals to live symbiotically with sulphur bacteria. These trilobites lived in low-oxygen settings and derived nutrients from the sulphide processing bacteria harboured in their gills; they are usually found to the exclusion of other less tolerant species. The 505 million year old *Ogygopsis klotzi* may have exhibited a similar life habit. Support for this interpretation is provided by the dominance of *Ogygopsis klotzi* over all other trilobites at the location. In addition, the other biota at the site including rare specimens of the tubeworm *Byronia*, inarticulate brachiopods, and a few sponges (*Pirania*?) are consistent with a seep-community. The Mt. Stephen trilobite beds indicate a full spectrum of trophic levels that occur at modern day hydrothermal vent and seep sites.

Modern hot vents have communities of tube worms, crustaceans, and mollusks consuming a chemosynthetic bacterial food source and the larger predators like fish and squid are at the top of the food chain; these communities form oases of life in a deep sea desert. The Mt. Stephen beds have evidence of tubeworms, brachiopods, and trilobites, as well as the non-resident *Anomalocaris* acting as a possible predator. The abundance of anomalocarid claws may indicate that *Anomalocaris* was an opportunistic predator or scavenger as trilobites would have been most vulnerable to predation pressure while mineralizing a new exoskeleton after molting.

If *O. klotzi* had the ability to glean nutrients through the bacteria in its tissues it may have been able to claim these hydrothermal sites as an adult niche where molting and mating could occur free from the pressures of shallower, populated, photic areas on the carbonate platform. It is also possible that these organisms gathered at this site given that the mineral-rich waters may have aided precipitation of a new skeleton following molting.

The biometric analysis of the trilobite *Ogygopsis klotzi* includes numerous bivariate plots. The most diagnostic plots include cranidium length versus pygidium length and cranidium length versus cranidium width. In both cases the plotted data indicate anisometric growth and typically cluster into two groups. These two groups or clusters of data points would most likely be interpreted as indicating the presence of two molt stages. The smaller sized specimens are rare; they represent either a rare molt stage or possibly males. Trilobites like all other arthropods molt during their lifetime and thus leave an ontogenetic series of potential fossils. Trilobites increased the number of thoracic segments early in their life at each molt stage, but once a trilobite reached an adult stage the number of thoracic segments did not increase, although individuals continued to grow and molt. All of the specimens that we observed were of adult *Ogygopsis* despite our deliberate search for some smaller specimens with lower numbers of thoracic segments. The absence of juvenile *O. klotzi* may be related to having free-swimming larvae that left the seep areas with the flow of water currents. The cluster of data points for the larger sized specimens shows two poorly defined sub-clusters. These may indicate a third molt stage or a subtle form of sexual dimorphism. Overall, the data points do not form a series of clusters for the many adult molts that would be expected. Most modern crustaceans demonstrate sexual dimorphism based on size and this has been demonstrated for trilobites (Hughes and Fortey, 1995). The lack of significant discrimination of size classes may suggest that the majority of *O. klotzi* specimens were adult females. Modern female crustaceans apparently lay and or incubate eggs in warmer temperatures and usually high salinity. It is possible that female *O. klotzi* migrated to this site because of the elevated temperatures. The modern majid crab is known to incubate eggs near hot vents.

The dominant sedimentary structure seen on the calcareous shale slabs with trilobites were parallel laminations suggesting that the mud was largely derived

from suspension. However, a few current rippled cross-laminae were seen indicating the presence of minor currents. In addition, the exceptional preservation of these sedimentary structures can be accounted for by the virtual lack of any trace fossils. Particularly puzzling is the lack of any trilobite trails given the considerable evidence that they lived at this site for at least part of their lives. It is possible that very minor currents that may have been in part generated by the mixing of hot and cold waters would have obliterated these traces.

SUMMARY

On the basis of other considerations including biostratigraphy, Fletcher and Collins (1998; p. 426) stated that "it would appear that the conspicuous presence of *Ogygopsis* and the absence of the trilobite *Pagetia bootes* suggest that the Mount Stephen trilobite beds probably represent a restricted niche during the time immediately preceding the development of the phyllopod bed-type sequences of the Walcott Quarry Shale". It is possible that the site represented a protected or restricted niche where adult female specimens moved during reproduction practices. In addition, the presence of carbonate mud-mounds generated by hydrothermal vents suggests that the dominance of *Ogygopsis* at this site may be explained by a preference for a chemosymbiotic relationship with sulphur bacteria.

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