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Systematic revision of the trilobite genera *Laudonia* and *Lochmanolenellus* (Olenelloidea) from the lower Dyeran (Cambrian Series 2) of western Laurentia

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References

- Bergström, J. (1973) Organization, life, and systematics of trilobites. *Fossils and Strata*, 2, 1–69.
- Bohach, L.L. (1997) *Systematics and biostratigraphy of Lower Cambrian trilobites of western Laurentia*. Unpublished Ph.D. thesis, University of Victoria, 491 pp.
- Bordonaro, O.L. (1978) Sobre la presencia de la “Zona de *Antagmus-Onchocephalus*” del Cámbrico inferior en la quebrada de Zonda, Provincia de San Juan. *Acta Geológica Lilloana*, 14 (Supplement), 1–3.
- Cooper, G.A., Arellano, A.R.V., Johnson, J.H., Okulitch, V.J., Stoyanow, A. & Lochman, C. (1952) Cambrian stratigraphy and paleontology near Caboerca, northwestern Sonora, Mexico. *Smithsonian Miscellaneous Collections*, 119 (1), 1–184.
- Deiss, C. (1939) Cambrian formations of southwestern Alberta and southeastern British Columbia. *Bulletin of the Geological Society of America*, 50, 951–1026.
- Emmons, E. (1844) *The Taconic System; based on observations in New-York, Massachusetts, Maine, Vermont and Rhode-Island*. Carroll and Cooke, Printers, Albany, N.Y., 65 pp.
- English, A.M. & Babcock, L.E. (2010) Census of the Indian Springs Lagerstätte, Poleta Formation (Cambrian), western Nevada, USA. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 295, 236–244.
<http://dx.doi.org/10.1016/j.palaeo.2010.05.041>
- Fritz, W.H. (1972) Lower Cambrian trilobites from the Sekwi Formation type section, Mackenzie Mountains, northwest Canada. *Geological Survey of Canada Bulletin*, 212, 1–90.
- Fritz, W.H. (1975) Broad correlations of some Lower and Middle Cambrian strata in the North American Cordillera. *Geological Survey of Canada, Paper*, 75-1A, 533–540.
<http://dx.doi.org/10.4095/104639>
- Fritz, W.H. (1978) Upper (carbonate) part of Atan Group, Lower Cambrian, north-central British Columbia. *Geological Survey of Canada, Paper*, 78-1A, 7–16.
- Fritz, W.H. (1980) Two new formations in the Lower Cambrian Atan Group, Cassiar Mountains, north-central British Columbia. *Geological Survey of Canada, Paper*, 80-1B, 217–225.
- Fritz, W.H. (1992) Walcott's Lower Cambrian olenellid trilobites collection 61k, Mount Robson area, Canadian Rocky Mountains. *Geological Survey of Canada Bulletin*, 432, 1–65.
- Fritz, W.H. (1995) *Esmeraldina rowei* and associated Lower Cambrian trilobites (1f Fauna) at the base of Walcott's Waucoban Series, southern Great Basin, U.S.A. *Journal of Paleontology*, 69, 708–723.
- Fritz, W.H. (n.d.) *Lower Cambrian trilobites from Cassiar Mountains, British Columbia, Canada, and regional correlations*. Unpublished manuscript, Geological Survey of Canada, 72 pp.
- Fritz, W.H. & Mountjoy, E.W. (1975) Lower and early Middle Cambrian formations near Mount Robson, British Columbia and Alberta. *Canadian Journal of Earth Sciences*, 12, 119–131.
<http://dx.doi.org/10.1139/e75-013>
- Hall, J. (1861) Note upon the trilobites of the shales of the Hudson River Group in the town of Georgia, Vermont. In: Hitchcock, E., Hitchcock, E. Jr., Hager, A.D. & Hitchcock, C.H., *Report on the Geology of Vermont: Descriptive, Theoretical, Economical, and Scenographical, Volume 1*. Claremont Manufacturing Company, Claremont, N.H., pp. 367–372.
<http://dx.doi.org/10.5962/bhl.title.31803>
- Harrington, H.J. (1956) Olenellidae with advanced cephalic spines. *Journal of Paleontology*, 30, 56–61.
- Harrington, H.J., Henningsmoen, G., Howell, B.F., Jaanusson, V., Lochman-Balk, C., Moore, R.C., Poulsen, C., Rasetti, F., Richter, E., Richter, R., Schmidt, H., Sdzuy, K., Struve, W., Størmer, L., Stubblefield, C.J., Tripp, R., Weller, J.M. & Whittington, H.B. (1959) *Treatise on Invertebrate Paleontology. Part O. Arthropoda 1*. Geological Society of America and University of Kansas Press, 560 pp.
- Hazzard, J.C. (1933) Notes on the Cambrian rocks of the eastern Mohave Desert, California. *Bulletin of the Department of Geological Sciences, University of California*, 23 (2), 57–80.
- Hollingsworth, J.S. (1999) Proposed stratotype section and point for the base of the Dyeran stage. In: Palmer, A.R. (Ed.), *Laurentia 99: V Field Conference of the Cambrian Stage Subdivision Working Group. International Subcommission on Cambrian Stratigraphy. Utah, Nevada, California, U.S.A., September 12–22, 1999*. Institute for Cambrian Studies, Boulder, Colorado, pp. 38–42.
- Hollingsworth, J.S. (2006) Holmiidae (Trilobita: Olenellina) of the Montezuman Stage (Early Cambrian) in western Nevada. *Journal of Paleontology*, 80, 309–332.
[http://dx.doi.org/10.1666/0022-3360\(2006\)080\[0309:htootm\]2.0.co;2](http://dx.doi.org/10.1666/0022-3360(2006)080[0309:htootm]2.0.co;2)
- Hollingsworth, J.S. (2011) Lithostratigraphy and biostratigraphy of Cambrian Stage 3 in western Nevada and eastern California. In: Hollingsworth, J.S., Sundberg, F.A. & Foster, J.R. (Eds.), *Cambrian Stratigraphy and Paleontology of Northern Arizona and Southern Nevada. Museum of Northern Arizona Bulletin*, 67. Flagstaff, Arizona, pp. 26–42.
- Hollingsworth, J.S. & Babcock, L.E. (2011) Base of Dyeran Stage (Cambrian Stage 4) in the middle member of the Poleta Formation, Indian Springs Canyon, Montezuma Range, Nevada. In: Hollingsworth, J.S., Sundberg, F.A. & Foster, J.R. (Eds.), *Cambrian Stratigraphy and Paleontology of Northern Arizona and Southern Nevada. Museum of Northern Arizona Bulletin*, 67. Flagstaff, Arizona, pp. 256–262.
- Hopkins, M.J. (2010) *Intraspecific variation, its geographic structure, and the relationship between variation and duration*,

- with examples from Cambrian trilobites and Recent fiddler crabs.* Unpublished Ph.D. Dissertation, University of Chicago, 375 pp.
- Hopkins, M.J. (2011) Species-level phylogenetic analysis of pterocephaliids (Trilobita, Cambrian) from the Great Basin, western USA. *Journal of Paleontology*, 85, 1128–1153.
<http://dx.doi.org/10.1666/11-002.1>
- Hu, C.-H. (1971) Ontogeny and sexual dimorphism of Lower Paleozoic Trilobita. *Palaeontographica Americana*, 7 (44), 29–155.
- Hughes, N.C. (2007) The evolution of trilobite body patterning. *Annual Review of Earth and Planetary Sciences*, 35, 401–434.
<http://dx.doi.org/10.1146/annurev.earth.35.031306.140258>
- Hupé, P. (1953) Classe des Trilobites. In: Piveteau, J. (Ed.), *Traité de Paléontologie. Tome III. Les formes ultimes d'Invertébrés: Morphologie et évolution. Onychophores, Arthropodes, Échinodermes, Stomocordés*. Masson, Paris, pp. 44–246.
- Jell, P.A. & Adrain, J.M. (2003) Available generic names for trilobites. *Memoirs of the Queensland Museum*, 48 (2), 331–553.
- Lieberman, B.S. (1998) Cladistic analysis of the Early Cambrian olenelloid trilobites. *Journal of Paleontology*, 72, 59–78.
- Lieberman, B.S. (1999) Systematic revision of the Olenelloidea (Trilobita, Cambrian). *Bulletin of the Peabody Museum of Natural History, Yale University*, 35, 1–150.
- Lieberman, B.S. (2002) Phylogenetic analysis of some basal Early Cambrian trilobites, the biogeographic origins of the Eutrilobita, and the timing of the Cambrian Radiation. *Journal of Paleontology*, 76, 692–708.
[http://dx.doi.org/10.1666/0022-3360\(2002\)076<0692:paosbe>2.0.co;2](http://dx.doi.org/10.1666/0022-3360(2002)076<0692:paosbe>2.0.co;2)
- Lieberman, B.S. (2003) Biogeography of the Trilobita during the Cambrian radiation: deducing geological processes from trilobite evolution. *Special Papers in Palaeontology*, 70, 59–72.
- Linnarsson, J.G.O. (1871) Om några försteningar från Sveriges och Norges "Primordialzon". *Öfversigt af Kongliga Vetenskaps-Akademien Förfärlingar*, 6, 789–796.
- Lochman, C. (1953) Corrections to trilobites in "Cambrian stratigraphy and paleontology near Caborca, northwestern Sonora, Mexico". *Journal of Paleontology*, 27, 486–488.
- Lochman-Balk, C. (1956) *The Cambrian of the Rocky Mountains and southwest deserts of the United States and adjoining Sonora Province, Mexico*. XX Congreso Geológico Internacional XX Sesión, México. El Sistema Cámbrico, su Paleogeografía y el problema de su base. Part II: Australia, América, pp. 529–662.
- Matthew, G.F. (1888) On the classification of the Cambrian rocks in Acadia. *Canadian Record of Science*, 3, 71–81.
- McMenamin, M.A.S. (1987) Lower Cambrian trilobites, zonation, and correlation of the Puerto Blanco Formation, Sonora, Mexico. *Journal of Paleontology*, 61, 738–749.
- McNamara, K.J. (1978) Paedomorphosis in Scottish olenellid trilobites (Early Cambrian). *Palaeontology*, 21, 635–655.
- Nelson, C.A. (1962) Lower Cambrian-Precambrian succession, White-Inyo Mountains, California. *Geological Society of America Bulletin*, 73, 139–144.
[http://dx.doi.org/10.1130/0016-7606\(1962\)73\[139:lcswmc\]2.0.co;2](http://dx.doi.org/10.1130/0016-7606(1962)73[139:lcswmc]2.0.co;2)
- Nelson, C.A. (1976) Late Precambrian-Early Cambrian stratigraphic and faunal succession of eastern California and the Precambrian-Cambrian boundary. In: Moore, J.N. & Fritsche, A.E. (Eds.), *Depositional environments of Lower Paleozoic rocks in the White-Inyo Mountains, Inyo County, California*. Pacific Coast Paleogeography Field Guide, 1, pp. 31–42.
- Nelson, C.A. (1978) Late Precambrian-Early Cambrian stratigraphic and faunal succession of eastern California and the Precambrian-Cambrian boundary. *Geological Magazine*, 115, 121–126.
<http://dx.doi.org/10.1017/s0016756800041169>
- Nelson, C. & Durham, J.W. (1966) *Guidebook for field trip to Precambrian-Cambrian succession, White-Inyo Mountains, California*. Geological Society of America, Guidebook, 1966 Annual Meeting at San Francisco, California, 17 pp., 5 pls.
- Okulitch, V.J. (1951) A Lower Cambrian fossil locality near Addy, Washington. *Journal of Paleontology*, 25, 405–407.
- Pack, P.D. & Gayle, H.B. (1971) A new olenellid trilobite, *Biceratops nevadensis*, from the Lower Cambrian near Las Vegas, Nevada. *Journal of Paleontology*, 45, 893–898.
- Palmer, A.R. (1998a) A proposed nomenclature for stages and series for the Cambrian of Laurentia. *Canadian Journal of Earth Sciences*, 35, 323–328.
<http://dx.doi.org/10.1139/cjes-35-4-323>
- Palmer, A.R. (1998b) Terminal Early Cambrian extinction of the Olenellina: Documentation from the Pioche Formation, Nevada. *Journal of Paleontology*, 72, 650–672.
- Palmer, A.R. & Halley, R.B. (1979) Physical stratigraphy and trilobite biostratigraphy of the Carrara Formation (Lower and Middle Cambrian) in the southern Great Basin. *United States Geological Survey Professional Paper*, 1047, 1–131.
- Palmer, A.R. & Repina, L.N. (1993) Through a glass darkly: Taxonomy, phylogeny, and biostratigraphy of the Olenellina. *University of Kansas Paleontological Contributions, New Series*, 3, 1–35.
- Peach, B.N. (1894) Additions to the fauna of the *Olenellus*-Zone of the Northwest Highlands. *Quarterly Journal of the Geological Society of London*, 50, 661–676.
<http://dx.doi.org/10.1144/gsl.jgs.1894.050.01-04.44>
- Peng, S., Babcock, L.E. & Cooper, R.A. (2012) The Cambrian Period. In: Gradstein, F.M., Ogg, J.G., Schmitz, M.D. & Ogg, G.M. (Eds.), *A Geologic Time Scale 2012*. Elsevier, Oxford, pp. 437–488.
<http://dx.doi.org/10.1016/b978-0-444-59425-9.00019-6>
- R Core Team (2013) *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna,

- Austria. Available from: <http://cran.us.r-project.org> (accessed 30 September 2013)
- Rasetti, F. (1951) Middle Cambrian stratigraphy and faunas of the Canadian Rocky Mountains. *Smithsonian Miscellaneous Collections*, 116 (5), 1–277.
- Resser, C.E. (1928) Cambrian fossils from the Mohave Desert. *Smithsonian Miscellaneous Collections*, 81 (2), 1–14.
- Resser, C.E. (1936) Second contribution to nomenclature of Cambrian trilobites. *Smithsonian Miscellaneous Collections*, 95 (4), 1–29.
- Resser, C.E. & Howell, B.F. (1938) Lower Cambrian *Olenellus* Zone of the Appalachians. *Bulletin of the Geological Society of America*, 49, 195–248.
- Richter, R. (1932) Crustacea (Paläontologie). In: Dittler, R., Joos, G., Korschelt, E., Linek, G., Oltmanns, F. & Schaum, K. (Eds.), *Handwörterbuch der Naturwissenschaften*. 2nd Edition. Gustav Fisher, Jena, pp. 840–846.
- Sadler, P.M. (2010) Brute-force biochronology: sequencing paleobiologic first- and last-appearance events by trial-and-error. In: Alroy, J. & Hunt, G. (Eds.), *Quantitative Methods in Paleobiology*. Paleontological Society Papers, 16, p. 271–289.
- Smith, L.H. & Lieberman, B.S. (1999) Disparity and constraint in olenelloid trilobites and the Cambrian Radiation. *Paleobiology*, 25, 459–470.
- Stewart, J.H. (1970) Upper Precambrian and Lower Cambrian strata in the southern Great Basin, California and Nevada. *United States Geological Survey Professional Paper*, 620, 1–206.
- Stewart, J.H., McMenamin, M.A.S. & Morales-Ramirez, J.M. (1984) Upper Proterozoic and Cambrian rocks in the Caborca region, Sonora, Mexico - Physical stratigraphy, biostratigraphy, paleocurrent studies, and regional relations. *United States Geological Survey Professional Paper*, 1309, 1–36.
- Walcott, C.D. (1890) The fauna of the Lower Cambrian or *Olenellus* Zone. In: *Tenth Annual Report of the Director, 1888–1889*, *United States Geological Survey*, pp. 509–774.
- Walcott, C.D. (1910) Cambrian Geology and Paleontology, Number 6: *Olenellus* and other genera of the Mesonacidae. *Smithsonian Miscellaneous Collections*, 53, 231–422.
- Walcott, C.D. (1913) Cambrian Geology and Paleontology. II. No. 11. New Lower Cambrian Subfauna. *Smithsonian Miscellaneous Collections*, 57 (11), 309–327.
- Wanner, A. (1901) A new species of *Olenellus* from the Lower Cambrian of York County, Pennsylvania. *Proceedings of the Washington Academy of Sciences*, 3, 267–272.
- Warton, D.I., Duursma, R., Remko, A., Falster, D.S. & Taskinen, S. (2012) smatr 3 – an R package for estimation and inference about allometric lines. *Methods in Ecology and Evolution*, 3, 257–259.
<http://dx.doi.org/10.1111/j.2041-210x.2011.00153.x>
- Webster, M. (2007a) Ontogeny and evolution of the Early Cambrian trilobite genus *Nephrolenellus* (Olenelloidea). *Journal of Paleontology*, 81, 1168–1193.
<http://dx.doi.org/10.1666/06-092.1>
- Webster, M. (2007b) *Paranephrolenellus*, a new genus of Early Cambrian olenelloid trilobite. *Memoirs of the Association of Australasian Palaeontologists*, 34, 31–59.
- Webster, M. (2009) Ontogeny, systematics, and evolution of the effaced early Cambrian trilobites *Peachella* Walcott, 1910 and *Eopeachella* new genus (Olenelloidea). *Journal of Paleontology*, 83, 197–218.
<http://dx.doi.org/10.1666/08-106.1>
- Webster, M. (2011) Trilobite biostratigraphy and sequence stratigraphy of the Upper Dyeran (traditional Laurentian “Lower Cambrian”) in the southern Great Basin, U.S.A. In: Hollingsworth, J.S., Sundberg, F.A. & Foster, J.R. (Eds.), *Cambrian Stratigraphy and Paleontology of Northern Arizona and Southern Nevada*. Museum of Northern Arizona Bulletin, 67. Flagstaff, Arizona, pp. 121–154.
- Webster, M. (2014) Ontogeny and intraspecific variation of the early Cambrian trilobite *Olenellus gilberti*, with implications for olenelline phylogeny and macroevolutionary trends in phenotypic canalization. *Journal of Systematic Palaeontology*.
<http://dx.doi.org/10.1080/14772019.2013.852903>
- Webster, M., Sheets, H.D. & Hughes, N.C. (2001) Allometric patterning in trilobite ontogeny: testing for heterochrony in *Nephrolenellus*. In: Zelditch, M.L. (Ed.), *Beyond Heterochrony: The Evolution of Development*. Wiley and Sons, New York, pp. 105–144.
- Webster, M., Sadler, P.M., Kooser, M.A. & Fowler, E. (2003) Combining stratigraphic sections and museum collections to increase biostratigraphic resolution. In Harries, P.J. (Ed.), *High-Resolution Approaches in Stratigraphic Paleontology*. Topics In Geobiology, Volume 21. Kluwer Academic Publishers, Dordrecht, pp. 95–128.
http://dx.doi.org/10.1007/978-1-4020-9053-0_3
- Whittington, H.B. (1957) Ontogeny of *Elliptocephala*, *Paradoxides*, *Sao*, *Blainia* and *Triarthrus* (Trilobita). *Journal of Paleontology*, 31, 934–946.
- Whittington, H.B. (1989) Olenelloid trilobites: Type species, functional morphology and higher classification. *Philosophical Transactions of the Royal Society of London, Series B*, 324, 111–147.
<http://dx.doi.org/10.1098/rstb.1989.0041>
- Whittington, H.B. (1990) Articulation and exuviation in Cambrian trilobites. *Philosophical Transactions of the Royal Society of London, Series B*, 329, 27–46.
<http://dx.doi.org/10.1098/rstb.1990.0147>
- Whittington, H.B., Chatterton, B.D.E., Speyer, S.E., Fortey, R.A., Owens, R.M., Chang, W.T., Dean, W.T., Jell, P.A., Laurie,

- J.R., Palmer, A.R., Repina, L.N., Rushton, A.W.A., Shergold, J.H., Clarkson, E.N.K., Wilmot, N.V. & Kelly, S.R.A. (1997) *Treatise on Invertebrate Paleontology. Part O. Arthropoda 1. Trilobita, Revised. Volume 1: Introduction, Order Agnostida, Order Redlichiida*. Geological Society of America and University of Kansas, Boulder, Colorado and Lawrence, Kansas, 530 pp.
- Young, F.G. (1972) Early Cambrian and older trace fossils from the southern Cordillera of Canada. *Canadian Journal of Earth Sciences*, 9, 1–17.
<http://dx.doi.org/10.1139/e72-001>