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Widespread, prolonged late Middle to Late Ordovician upwelling in North America: A proxy record of glaciation?: Comment and Reply

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Notes

Forum

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COMMENT

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Pope and Steffen (2003) described an interesting new model suggesting relations between the Gondwana glaciation and late Middle (Chatfieldian) through Late Ordovician (Cincinnatian) upwelling of cold water and chert formation. They used the distribution of Middle and Late Ordovician chert-bearing units as evidence to support their conclusion of glaciation lasting 10–14 m.y. rather than 1 m.y. or less. However, the listed age of many of their chert-bearing units is incorrect, and this directly bears on their conclusions. Some of the incorrect formation ranges may be due to the fact that the authors have followed imprecise secondary references but this can hardly explain why they place the North American standard Chatfieldian Stage (Leslie and Bergström, 1995) below, rather than above, the Turinian Stage in both their Figures 2 and 4. Further, the base of the Maravillas Formation is now firmly dated as Richmondian, not Middle Ordovician (Goldman et al., 1995) as are the upper part of the Viola Group (Goldman and Bergström, 1997) and the Aleman Formation. The Womble Shale has nothing to do with the Sylvan Shale—it underlies the Bigfork Chert and is of Middle Ordovician (Turinian) age (Finney, 1986), and the Simpson Group is not recognized in the Bigfort-Womble distribution area. No early Hirnantian strata have been recognized in the Maravillas Formation of West Texas or in the eastern Midcontinent. Their Figure 4 shows numerous errors in the ranges of the stratigraphic units. Hence, the Anthill Shale is Early Ordovician (Cooper, 1979). The virtually unfossiliferous Mallacoota Beds appear to range from the Early through the Late Ordovician (Webby et al., 1981), but the only fossils found are of Middle Ordovician age. The age of the unfossiliferous Girilambone Group is taken to be Cambrian or Early Ordovician (Webby et al., 1981). The Tallebung Formation is late Middle to early Late Ordovician in age. The Portixeddu Formation of Sardinia represents a narrow interval near the Caradocian-Ashgillian boundary (Leone et al., 1991) with conodonts (Ferretti and Serpagli, 1999) referable to the *Amorphognathus superbus* zone (upper Maysvillian or lowermost Richmondian). The Postolonnec-Kermeur succession in France ranges from the Early Ordovician to about halfway up in the Late Ordovician (Hammann et al., 1982). The unit below the Maravillas Formation in West Texas is not the Fort Peña Formation but the Turinian Woods Hollow Shale, which is underlain by the early Middle Ordovician Fort Peña Formation (Berry, 1960). Recent studies support the classic idea that the Ely Springs, Saturday Mountain, and Whittaker Formations, as well as an unnamed Sonora unit, are likely to represent only the Richmondian Stage. Figure 1 summarizes the stratigraphic unit ranges compared to those given in Pope and Steffen (2003). It shows that the ranges of these chert-bearing units are far more scattered than previously indicated, which makes the use of the presence of chert as support for an extended, late Middle–Late Ordovician glacial period more tenuous. We also note that abundant chert is also present in Laurentia in shallow-water sediments with tropical faunas that are unlikely to have been affected by cold-water upwelling, for instance, the Lower Ordovician Jefferson City and Middle Ordovician Plattin of Missouri.

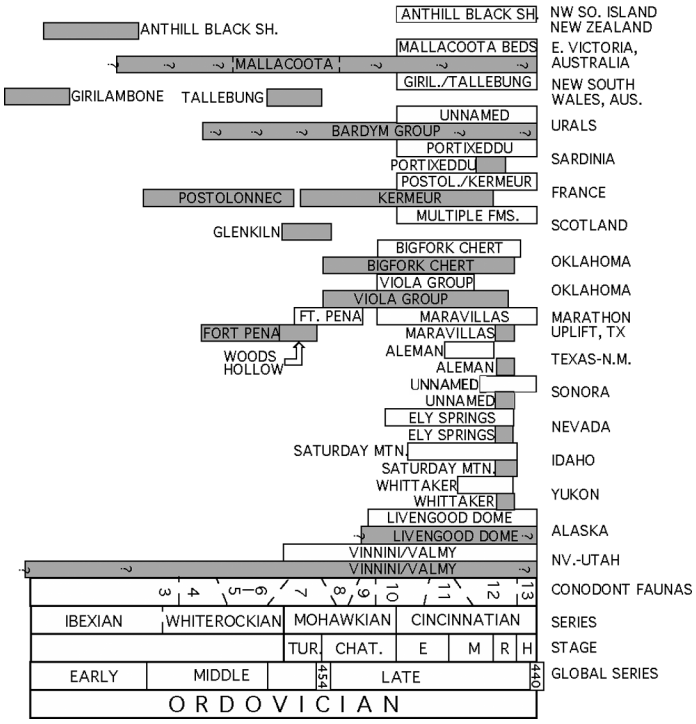

Figure 1. Stratigraphic range chart showing unit ages reported by Pope and Steffen (2003, their Figs. 2 and 4) (white boxes) compared to more precisely established ranges of the same units (gray boxes). N.M.—New Mexico; NV.—Nevada; TX.—Texas; TUR.—Turinian; CHAT.—Chatfieldian; E—Edenian; M—Maysvillian; R—Richmondian; and H—Hirnantian.

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REPLY

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I welcome Leslie and Bergström's comment on our recent article (Pope and Steffen, 2003); it allows me the opportunity to clarify and reiterate some points in that article. The comment makes a number of points that I have labeled 1–6, and I address them in the general order they occur in the comment.

1. As noted in the erratum published in *Geology* (v. 31, p. 656), we inadvertently transposed the position of the Turinian and Chatfieldian stages in Figures 2 and 4 in our original article. Similarly, the Polk Creek Shale is equivalent to the Sylvan Shale and should have been listed in the position of the Womble Shale on our original Figure 2. These were unfortunate oversights, and I regret the errors.

2. Simpson Group rocks *are* interpreted to occur in the subsurface of eastern Texas and they outcrop in the Arbuckle Mountains of Oklahoma, immediately below the Viola Group (Suhm, 1997; Denison, 1997).

3. We did not mean to imply that early Hirnantian strata are recognized in the Maravillas or Late Ordovician eastern Midcontinent rocks. However, the new biostratigraphy of the Maravillas Formation (Goldman et al., 1995) was from one section (Picnic Grounds) that does not include a 20–30 m thick cherty shale that McBride (1989) demonstrated occurred above the cherty carbonates; thus, we still contend the upper age of the Maravillas is uncertain. Similarly, sporadic outcrops of Hirnantian iron ooidstones (e.g., Keel, Noix, Queenston Formation) overlying more widespread Late Ordovician carbonates in the Midcontinent (Van Houten, 1990) indicate there is some deposition in North America during this period.

4. We used Hein and Parrish (1987) as our starting point for the age constraints on Late Ordovician cherty carbonates and cherty shale units outside of North America that were used in Figure 4. We updated this citation through an extensive GEOREF search that did not provide the newer age correlations cited by Leslie and Bergström. We welcome these new dates and agree that some of them, if substantiated, likely have nothing to do with enhanced upwelling during a prolonged Late Ordovician glaciation.

5. Figure 4 in the original article shows units with depositional chert so the Woods Hollow Shale was omitted because it does not contain any chert, whereas the Fort Peña Formation was included because it does have subtidal chert, which we interpreted to possibly form by upwelling. Similarly, a number of Early, Middle, and Late Ordovician chert-rich carbonates (e.g., Jefferson City and Plattin) units were not listed on Figure 4 because their chert formed in peritidal settings through a variety of processes (i.e., evaporation, late diagenetic replacement by groundwater or burial fluids, silica migration from bentonites, etc.) that have nothing to do with oceanic upwelling.

6. Leslie and Bergström's contention that the Montoya Formation, specifically the Aleman Formation and its correlative chert-rich carbonates in Texas, Oklahoma, and the Great Basin are confined to the Richmondian stage stands in stark contrast to published conodont data from these units indicating they were deposited during the Maysvillian to Richmondian (Sweet, 1979, 2000; Poole et al., 1995). For example, the Aleman Formation contains conodont elements of both the *Amorphognathus superbus* and *Amorphognathus ordovicicus* zones and spans a portion of conodont Faunas 11 and 12 (Sweet, 1979), which Leslie and Bergström concede occur during the Maysvillian (see Fig. 1 of their comment). Thus, until new data on these units is published, we will continue to contend these units were deposited over a longer period of time than suggested by Leslie and Bergström.

The larger issue, which Leslie and Bergström do not dispute, is that no matter if these chert-rich units are only Richmondian or span from the Edenian to Richmondian, they formed over a broad area by upwelling. If we are correct, and this upwelling was enhanced by ocean circulation driven by thermohaline currents caused by glaciation, then the enigmatic Late Ordovician glaciation was not limited to the Hirnantian (e.g., Brenchley et al., 1994).

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