Geology

Carboniferous age for the East Greenland "Devonian" basin: Paleomagnetic and isotopic constraints on age, stratigraphy, and plate reconstructions: Comment and Reply

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Carboniferous age for the East Greenland "Devonian" basin: Paleomagnetic and isotopic constraints on age, stratigraphy, and plate reconstructions: Comment and Reply

COMMENT

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Hartz et al. (1997) suggested an Early Carboniferous age for the main part of the Devonian basin in East Greenland based on paleomagnetic and radiometric age data. They stressed the important implications of this age assignment for early vertebrate evolution, plate reconstructions, and timing of late Paleozoic rifting events in the northern North Atlantic. Hartz et al. (1997) did not, however, refer to any biostratigraphic studies from the region that could support their conclusions.

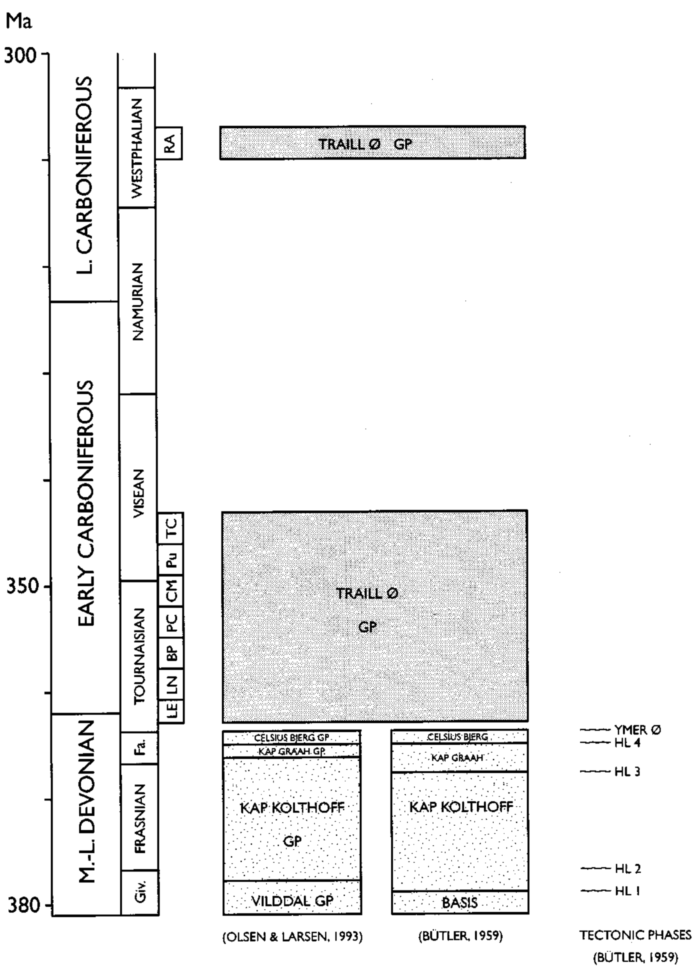

Figure 1. Devonian-Carboniferous stratigraphy of East Greenland. The old names of Bütler (1959) preferred by Hartz et al. (1997) for the Devonian basin are shown together with the modern stratigraphic scheme of Olsen and Larsen (1993). Uppermost Devonian–Carboniferous data are modified from Stemmerik et al. (1991). HL—Hudson Land. LE, LN, BP, PC, CM, Pu, TC and RA are northwest European miospore zones of Clayton et al. (1977) and Higgs et al. (1988).

The proposed Early Carboniferous age of the Devonian sediments is in direct conflict with published biostratigraphic data from the region. South of their study area the Devonian sediments and volcanic rocks described by Hartz et al. (1997) are unconformably overlain by a palynologically well dated succession of continental deposits ranging in age from latest Devonian (earliest Tournaisian) to late Carboniferous (Fig. 1) (Stemmerik et al., 1991). These ages constrain the minimum age of the Devonian sediments; they cannot be younger than earliest Tournaisian in age. The biostratigraphically dated latest Devonian–Carboniferous sediments are unaffected by the Hudson Land and Ymer Ø tectonic phases that resulted in the unconformities between the Basis and Kap Kolthoff, Kap Kolthoff and Kap Graah, Kap Graah and Celsius Bjerg Series of the Devonian basin shown by Hartz et al. (1997, Fig. 1), as well as in the top Devonian unconformity (Bütler, 1959). They unconformably overlie the *Ichthyostega*-bearing Celcius Bjerg Series in eastern Ymer Ø and northern Geographical Society Ø. There the oldest sediments belong to the *Retispora lepidophyta* assemblage, which is correlated with the LE and LN miospore zones of Tournaisian T1a and T1b age in northwest Europe (see Fig. 1) (Clayton et al., 1977; Higgs et al., 1988; Stemmerik et al., 1991). This biostratigraphic age is close to 365 Ma according to the time scale of Harland et al. (1990) and is older than the radiometric age of 336 Ma recorded for the Devonian basalts much lower in the succession by Hartz et al. (1997). It is, however, interesting to note that the latter age corresponds to a major late Visean to early Westphalian (310–343 Ma) hiatus in the Carboniferous succession in East Greenland and elsewhere in the northern North Atlantic and Barents Sea area (Stemmerik et al., 1993; Stemmerik et al., 1991), and is close to cooling ages of 314 Ma and 320 Ma based on biotite and muscovite from banded gneiss and pegmatite farther to the north in East Greenland (Dallmeyer and Strachan, 1994; Steiger et al., 1976). The 336 Ma age obtained from the Devonian volcanic rocks is evidently not an extrusion age but may be a cooling age related to a regional mid-Carboniferous uplift of the entire northern North Atlantic region.

From biostratigraphic data it is thus indisputable that the Devonian basin with *Ichthyostega* and its associated fauna is of pre-Tournaisian, Devonian age. The more precise age of the Kap Graah and Celsius Bjerg Groups (sensu Olsen and Larsen, 1993) is Famennian based on comparison of the rich fauna of *Bothriolepis*, *Remigolepis*, *Phyllolepis*, *Soederberghia*, *Jarvikia*, *Nielsenia*, *Oervigia*, *Holoptychius*, and *Eusthenodon* (Bendix-Almgreen, 1976; Bendix-Almgreen in Jarvik, 1996; Bendix-Almgreen et al., 1990). The Hartz et al. (1997) paper is an unfortunate example of reliance on geophysical and radiometric data for dating of stratigraphic successions without integration of available biostratigraphic data. Accordingly, the regional tectonic, paleomagnetic, and evolutionary implications of their data need to be reevaluated within a proper chronostratigraphic framework.

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REPLY

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We welcome the comment of Stemmerik and Bendix-Almgreen and are pleased that our paper has led to a debate on time-scale calibrations. Stemmerik and Bendix-Almgreen suggest that the young age (~336 Ma) for the "Devonian" basalts and sediments in East Greenland cannot be correct, as fossils inferred to be overlying the basalts are regarded as Famennian in age (376.5–362 Ma, Tucker et al., 1997). However, correlation between the biostratigraphic time scale and absolute ages is continuously modified, and new but controversial data should always be considered.

Stemmerik and Bendix-Almgreen present a layer-cake stratigraphic column with continuous deposition for the basin (their Fig. 1), based upon interbasinal lithostratigraphic correlations. However, in this column, sediments are grouped together across major peneplaned erosional-transgressive surfaces, marked by top lap–on lap unconformities. The Middle Devonian to Early Permian basins in East Greenland formed in an active tectonic setting, and we argue that the basin is best portrayed by continental sequence stratigraphy. An example of this can be seen in the unconformities below Kap Graah Group and Kap Koltholt Group, occurring in the eastern and western side of the basin, which Stemmerik and Bendix-Almgreen place in succession (their Fig. 1), although they are roughly time equivalent, regardless of their absolute age (Hartz et al., 1997). Hiatuses will not be given proper attention when time-equivalent deposits are stacked in stratigraphic columns, and a condensed biostratigraphy will thereby appear to be continuous.

We believe that there is still much to discover about the late Paleozoic basin architecture in East Greenland, and we are therefore surprised that Stemmerik and Bendix-Almgreen argue that "indisputable" stratigraphic evidence show that *Ichthyostega is* Famennian when the exact stratigraphic position of the sampled tetrapods is unknown (Clack, 1997). In fact, Jarvik (1952) collected his famous fossils from a talus deposit.

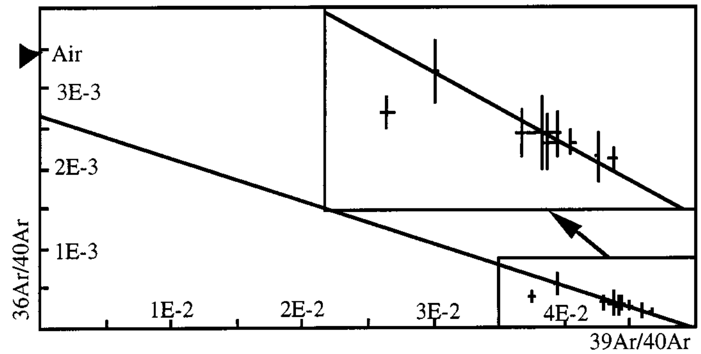

Figure 1. Inverse isochron giving an age of 333 ± 12 Ma (2σ) and an initial $^{36}Ar/^{40}Ar$ ratio of 377 ± 87 (MSDW = 1.62, the preheating step plotting below the isochron is not included).

Stemmerik and Bendix-Almgreen argue that our data record regional cooling in the entire East Greenland region, by comparing the age of the basalt with similar Ar-Ar ages from high-grade gneisses reported from North-East Greenland by Dallmeyer and Strachan (1994) and others. The basalts occur in a nonmetamorphic supra-detachment basin and are therefore irrelevant to rocks in a late to post Caledonian metamorphic core complex, which record cooling by uplift along a crustal-scale extensional detachment. We tested the issue of thermal resetting by dating detrital feldspars from sediments occurring next to the basalts. These are ~70 m.y. older than the basalts and compare to cooling ages from the basin substrata.

In our original paper we presented a plateau age for the basalt. An inverse isochron plot of the same data (Fig. 1) show a well-defined isochron, which overlaps in age the published plateau age of ~336 Ma. The initial $^{36}Ar/^{40}Ar$ ratio is higher than the ratio in air, suggesting inheritance of (excess) argon, rather than argon loss. If anything, the recorded plateau age in our original paper therefore is slightly too old.

The paleomagnetic data we presented cannot accurately date the red beds and the basalts, but Late Devonian and Early Carboniferous ages are indicated below and above conformities, respectively. For elementary reasons, the paleomagnetic data cannot represent a regional overprint. First, a regional overprint would have produced the same magnetization throughout the entire basin, and second, the magnetic reversal stratigraphy must be a primary nature, hence excluding resetting by metamorphism. Our data therefore do not record regional cooling, and we therefore maintain that there is no experimental reasons to reject the young ages. Further isotopic studies are essential and these are indeed in progress.

Stemmerik and Bendix-Almgreen state that our paper show an "unfortunate example of reliance on geophysical and radiometric data," and that our data need to be "re-evaluated within a proper chronostratigraphic framework." Stemmerik and Bendix-Almgreen, however, use circular argumentation as they reject our absolute ages and instead choose to correlate the East Greenland fossils with fossils from areas with no absolute ages (e.g., Clayton et al., 1977). Conversely, we approach the problem by dating extrusive rocks directly interbedded with referenced fossils using both U-Pb and Ar-Ar methods.

In conclusion, we welcome the comment by Stemmerik and Bendix-Almgreen as an illustration of the ongoing challenges of time-scale correlation, and suggest that the rich fossil fauna interbedded with bimodal volcanic rocks in East Greenland represent an exciting opportunity for isotope geologists and biostratigraphers to collaborate.

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CORRECTION

Bed-form dynamics: Does the tail wag the dog?

Geology, v. 25, p. 771–774 (September 1997)

Equations 2b and 7 were printed incorrectly. The corrected equations are given here.

$$\tilde{v}_{T,AT_{\parallel}} = \pm \frac{Q\cos\left(\alpha \mp \beta_{T,AT}\right)}{h/2} \mp \frac{Q\left[\cos\alpha - \cos\left(\alpha \mp \beta_{T,AT}\right)\right]}{h} \quad (2b)$$

$$\tan\alpha_1 = -\sigma\left(\frac{1}{|\tan\Delta\alpha|} + \frac{1}{|\sin\Delta\alpha|}\right) \quad (7)$$

CORRECTION

High-resolution seismic reflection profiles from Lake Titicaca, Peru-Bolivia: Evidence for Holocene aridity in the tropical Andes

Geology, v. 26, p. 167–170 (February 1998)

Figures 2 and 3 were reversed. The figures are reprinted here with their correct captions.

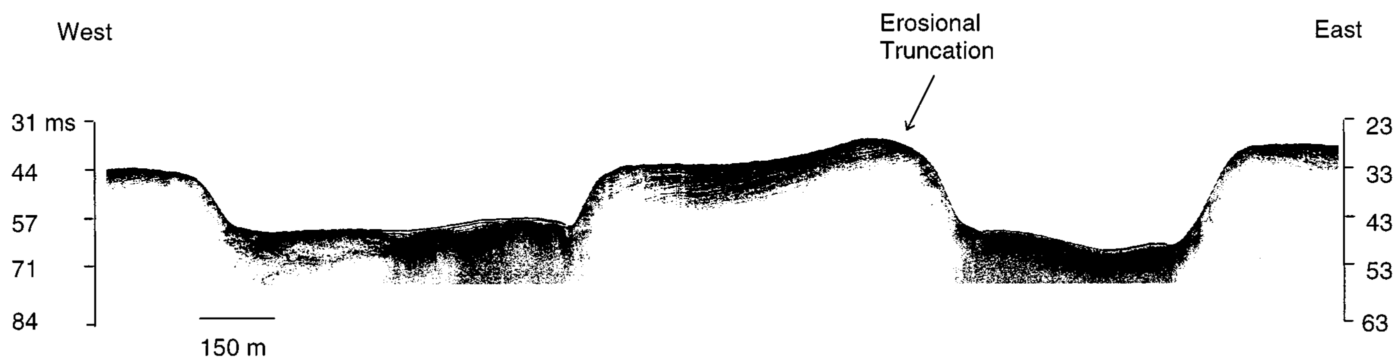

Figure 2. Erosional channels in strait that connects Puno Bay with Lago Chucuito. Depths in this figure and in Figures 3–5 were determined by assuming P-wave velocity of 1500 m/s. Time is expressed in milliseconds of two-way traveltime. Depths in text were determined by adding 4 m (water depth of source receiver) to depths indicated in these figures and rounded to nearest 5 m.

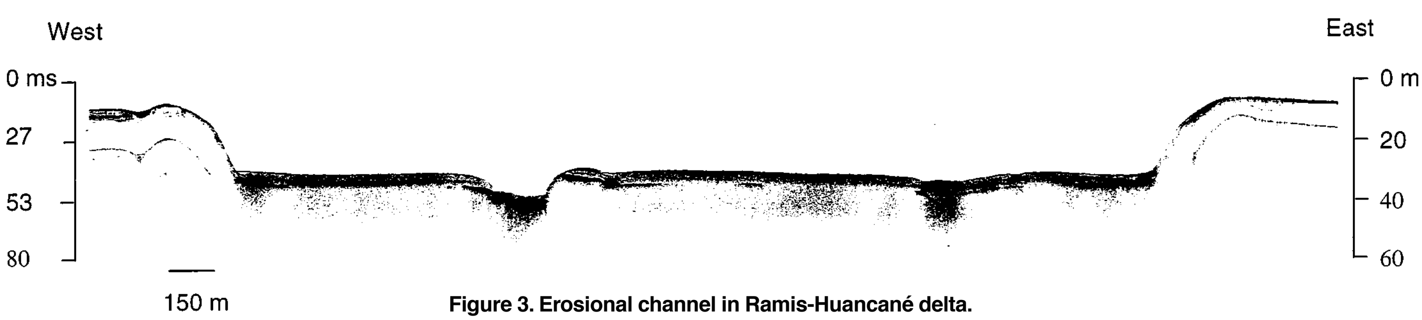

Figure 3. Erosional channel in Ramis-Huancané delta.