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Discussion

Reply to: Comment on "Apatite Fission Track and (U–Th)/He data from Fennoscandia: An example of underestimation of fission track annealing in apatite" by B. W. H. Hendriks and T. F. Redfield

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Abstract

In the absence of any remnant sedimentary rocks or other tangible geological evidence, Apatite Fission Track (AFT) data from Fennoscandia have been interpreted in terms of deep burial beneath a Caledonian foreland basin. We rejected this interpretation of AFT data from central Finland in 2005, in favor of one incorporating radiation enhanced annealing over geologically extended periods of time. The physics underlying our hypothesis have been discussed extensively during the past two decades by various peer-reviewed studies. In this Reply we contend that, in their Comment, Larson et al. incorrectly interpret published geological data to support deep burial beneath an aerially extensive Caledonian foreland basin. We show the Avalonia–Baltica tectonic collision better explains data that intimate slightly elevated paleo-temperatures and paleo-pressures in southern Sweden. We demonstrate that most of the geological data cited by Larson et al. are geographically isolated from the area we discussed in our 2005 contribution, and thus completely unrelated to our conclusions. We consider the Comment by Larson et al. as unfounded, and consequently uphold our original interpretation.

Keywords: apatite; fission track; (U–Th)/He; annealing; radiation; craton

1. Introduction

When Apatite Fission Track (AFT) modelling results and geological data conflict, only two possibilities exist: the annealing models used to extract thermal histories from AFT data do not provide accurate results [1], or the 'accepted geological data' are wrong (e.g. [2]). In their Comment, Larson et al. [3] seek to resolve the conflict by claiming the 'accepted' Fennoscandian geological record negates the conclusions we drew [1]. However, we contend their AFT interpretation [3] is in error.

Only one of the geological constraints Larson et al. [3] present in favor of a deep, extensive foreland basin in Fennoscandia (post-Ordovician ages for galena bearing veins) comes from Finland, the area where we [1] observed discrepancies between closely-spaced AFT data (Fig. 1). Their use of the galena data is misleading: the original authors [4] explicitly described the ages as neither accurate nor indicative of elevated temperatures in the crystalline basement (see quotations below). The remainder of the constraints presented by Larson et al.

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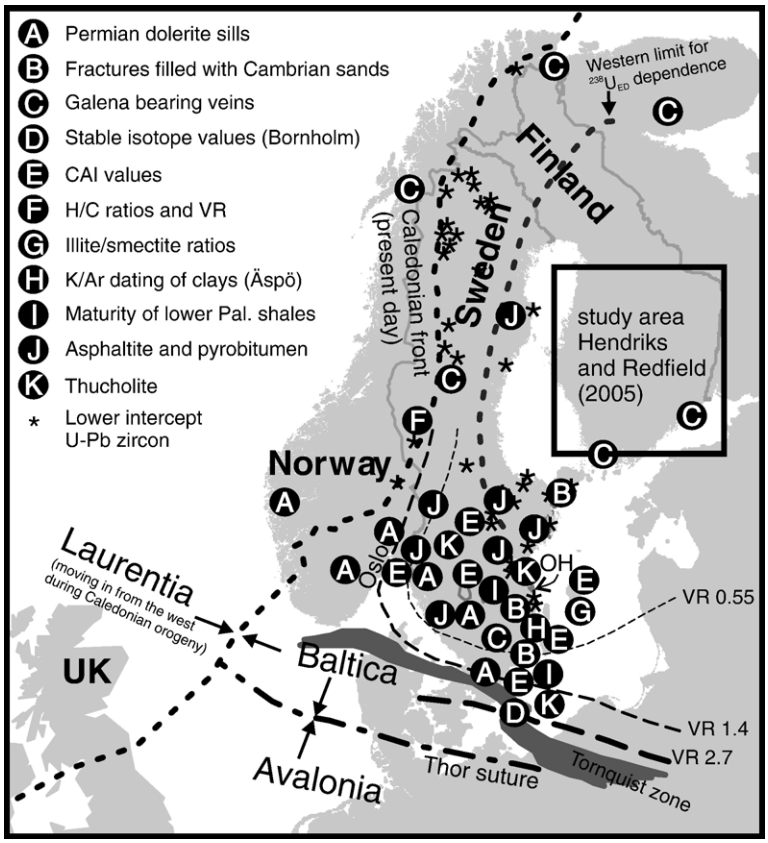

Fig. 1. Location map showing sites cited by Larson et al. [3]. Distribution of Permian dolerite sills according to Heeremans et al. [5]. Vitrinite Reflectance (VR) isolines for Alum shale as in Torsvik and Rehnström [6]. Thor suture and Tornquist zone after Pharaoh [7]. Stars denote sampling sites for lower intercept U–Pb zircon data [8]). OH refers to Oskarshamn, study area for Söderlund et al. [9]. Western limit for $^{238}U_{ED}$ dependence after Hendriks and Redfield [1]. The present day location of the Caledonian front is outlined (note: this does not represent the location of the suture between Laurentia and Baltica, which is located further west).

[3] lie completely outside the area from which we drew our conclusions (Fig. 1), and thus have no bearing on our discussion of the potential importance of self-irradiation as a mechanism for shortening fission tracks in apatite.

To a certain degree, the Comment of Larson et al. [3] misrepresents a fundamental aspect of our 2005 contribution [1]. Well aware of the Late Silurian–Early Devonian existence of a high mountain range in western Scandinavia [10] we specifically noted that '*some Caledonian foreland basin sedimentation clearly must have occurred*'. We indicated that, even today, more than a kilometre of overburden that potentially may qualify as remnants of Caledonian foreland basin infill exists in the Oslo region, parts of southern Sweden, and the southern Baltic basin. In our paper [1] we specifically argued against the former existence of (quote) '*a sedimentary blanket sufficiently deep to cause significant thermal annealing of Apatite Fission Tracks*' (i.e. several kilometres) over '*eastern Sweden and central Finland.*'

Larson et al. [3] cite numerous geological studies that, in their opinion, "*strongly support the former existence of thick and extensive deposits on the Caledonian foreland.*" They further imply this hypothesis is 'accepted' by most Scandinavian geologists. However, five factors dispute them. 1) The data are geographically limited (Fig. 1): most come from southern Sweden, and none whatsoever from central Finland. 2) The data are temporally unconstrained: many are completely undateable, others are poorly dated, and none can be uniquely confined to the Late Silurian–Early Devonian Caledonian orogeny. 3) They are equivocal: there exist alternative explanations to the Caledonian foreland basin hypothesis for each observation, that in many cases are geologically much more plausible. 4) Some are circular, their conclusions depending for example on output from AFT models (e.g. [8]). 5) They are not wholly accepted