Discussion of

Evaluation of different models for the origin of the Siberian traps.

by

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15th January, 2007, Ajoy K. Baksi

Ivanov's assessment of aspects of Siberian Trap volcanism serves as a useful adjunct to our knowledge about flood basalt volcanism. However, numerous ages used therein, do not qualify as proper estimates of the crystallization ages; that is $^{40}Ar/^{39}Ar$ ages need to be evaluated for both statistical validity, as well as freshness of samples dated (Baksi, this volume).

Firstly, the ages reported in Baksi and Farrar (1991a) are known to be incorrect both on the basis of mass spectrometric problems as well as ages of standards used (Baksi, 2005, Baksi and Farrar, 1991b). These analyses are now evaluated for freshness (Baksi, 2007). The plateau steps for ST-154 (K = 0.60%) and ST-524 (K = 0.13%) give A.I. values in the range 0.044 – 0.0030 and 0.020 – 0.0015, respectively. The cutoff for freshness is < 0.0006; both rocks are altered and cannot give proper estimates of the time of crystallization. ST-563 is a dyke and its A.I. cannot be unequivocally used for a freshness test – see Discussion on Baksi (2007). The ages of Walderhaug et al. (2005) must all be discounted as they fail statistical tests for proper plateaus and/or are altered as based on the A.I. test. Earlier efforts (Renne and Basu, 1991; Dalrymple et al., 1995; Venkatesan et al., 1997; Reichow et al., 2002) must all be critically evaluated, in particular by the alteration index technique. This is not always possible as some of the data sets are currently not available for examination. Some of the analyses fail the freshness test; the major portions of mafic rocks appear to have been extruded in ~1 Ma around 250 Ma. The best (U-Pb) ages are those of Kamo et al. (2003) at 252-251 Ma, and the screened $^{40}Ar/^{39}Ar$ ages are in general agreement with these.

The total duration of volcanism remains unknown. All relevant $^{40}Ar/^{39}Ar$ ages must be critically examined by the techniques set out earlier (see Baksi, 2007). I strongly urge scientists to carry out such critical examination FOR THEMSELVES, prior to advancing hypotheses related to the (temporal) formation of this immense province and its possible environmental effects.

19th January, 2007, Alexei Ivanov

Baksi (15th January) rises two important questions about (1) duration of the Siberian Traps and (2) reliability of published $^{40}Ar/^{39}Ar$ ages.

(1) The U-Pb ages of Kamo et al. (2003) were obtained on samples from a localized area compared to the whole Siberian Traps and propagation of these ages to other remote regions is questionable. A paleomagnetic study in the Noril'sk area shows that volcanism started there at the end of a reversed polarity chron (latest Permian) and continued during a normal polarity chron (earliest Lower Triassic) (e.g. Heunemann et al. (2004)). A paleomagnetic study of volcanic rocks recovered from the super-deep drill hole No 6 (SG-6) within the West Siberian Basin revealed 5 normal and 4 reversal polarity chrons, suggesting a duration of volcanism from the Tatarian to the end of the Olenekian (end of the Lower Triassic; roughly 9 Ma duration). As for the Walderhaug et al. (2005) paper whose Middle Triassic $^{40}Ar/^{39}Ar$ ages on Taimyr dolerite sills were questioned by Baksi (15th January), these $^{40}Ar/^{39}Ar$ ages were complemented by a paleomagnetic study, which revealed paleomagnetic poles in agreement with sill emplacement in the Middle Triassic. U-Pb and $^{40}Ar/^{39}Ar$ ages obtained on the same lava units and intrusions appeared to be in good agreement, taking into accouont a slight systematic difference of <1 % (Ivanov, 2006). Among these, the Bolgokhtokh granodiorite intrusion is dated as old as 228.9 ± 0.3 Ma and 226.8 ± 0.8 Ma by U-Pb and $^{40}Ar/^{39}Ar$, respectively. (The original $^{40}Ar/^{39}Ar$ age (Dalrymple et al., 1995) is recalculated relative 98.5 Ma for GA1515 standard.) Similar types of intrusions are found elsewhere within Siberian Traps and dated by U-Pb from ca. 250 to ca 225 Ma (see references in Ivanov, this issue). Thus, long-lived magmatism of the Siberian Traps is expected, even if no $^{40}Ar/^{39}Ar$ ages had been published.

(2) As mentioned by Baksi (15th January), most published $^{40}Ar/^{39}Ar$ ages for the Siberian Traps are presented without full analytical details. So, AI (alteration index) suggested as measure of $^{40}Ar/^{39}Ar$ age reliability by Baksi (this issue) can be calculated only by the authors of those papers. Plateau steps from $^{40}Ar/^{39}Ar$ stepwise-heating dating of plagioclases from Ivanov et al. (2005) yielded negative AI values. The negative AI values are due to J factors of about 0.08, which is sufficiently low to fit the range of optimal production of ^{39}Ar and ^{37}Ar (e.g. Fig. 3-7 in McDougall and Harrison, 1999), but too high for the AI equation in Baksi (this issue). Should these plateau ages with negative AI be accepted? Probably yes, because the $^{36}Ar/^{37}Ar$ for plateau steps is low (0.00003-0.00017). The low temperature steps with too low apparent ages (Fig. 2 in Ivanov et al., 2005) are characterized by high AI up to 0.5, showing alteration of plagioclases at crystal edges and within cracks. The weighted mean of the two plateau ages is 243.9 ± 1.4 Ma (relative to 129.4 Ma for LP6) or 243.9 ± 5.8 Ma if possible subsampling inhomogeneity of LP6 is accounted for (Ivanov et al., 2005).

Baksi (15th January) reports that the AI for his samples (Baksi and Farrar, 1991a) varies between 0.0015 and 0.04 and he reject these ages as altered on basis of the cut-off value of 0.0006. Ivanov et al. (2006) dated 3 samples using the $^{40}Ar/^{39}Ar$ stepwise-heating technique. The samples yielded concordant plateau and isochron ages. Application of the method of Baksi (this issue) shows that for plateaus of these samples, AI is between 0.002 and 0.05. According to Baksi (this issue) these ages should be rejected. However, there are some arguments to keep these ages as true crystallization ages. First of all, the age for the Nadezhdinsky suite agrees within analytical uncertainty with those published by Venkatesan et al. (1997), whose ages are in agreement with the U-Pb ages of Kamo et al. (2003). Second, there is a difference between the ages obtained for

samples from the Nadezhdinsky and Hona-Makitsky suites, whereas there is no difference in their AI indices. Third, Baksi (this issue) acknowledges that the AI will be higher than the cut-off value in fresh samples of volcanic rocks, if they were derived from a subduction-derived water-bearing mantle source. I argue that the Siberian Traps (Ivanov, this issue) and probably other flood basalt provinces (see Ivanov, 17th January comment to discussion of Hooper et al., this issue) were derived from such mantle sources. Therefore, an AI cut-off value of 0.0006 may be not applicable for the Siberian Traps.

As to the rest, I fully agree with Baksi (15th January, this issue) that careful evaluation of $^{40}Ar/^{39}Ar$ data is essential for correct interpretation of geological models.

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