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IMPROVED U-PB DATING OF THE CA. 450 MA SUORDAKH MAFIC EVENT IN EASTERN SIBERIA WILL TEST WHETHER THIS IS THE MISSING LIP RELATED TO END-ORDOVICIAN MASS EXTINCTION: PROGRESS REPORT

Chamberlain K. R.[1,4], Khudoley A. K.[2,4], Ernst R. E.[3,4], Prokopiev A. V.[5]

[1]*Dept. of Geol. and Geophy., Univ. of Wyoming, Laramie WY USA 82071*
[2]*Geol. Dept., St. Petersburg State Univ., St. Petersburg, Russia*
[3]*Dept. Earth Sci., Carleton Univ., Ottawa, Canada 82071*
[4]*Faculty of Geology and Geography, Tomsk State University, Tomsk 634050, Russia*
[5]*Diamond & Precious Metal Geol. Inst., Russian Acad. of Sci., Yakutsk, Rep. Sakha (Yakutia), 677980, Russia*

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Introduction

The Suordakh north-south trending mafic dikes and associated sills are currently recognized over an area of 11,000 km^2 in the Verkhoyansk region of eastern Siberia (Figure 1), but candidates are possible over an area that is approximately 500 km long and 80 km wide (Khudoley et al. 2013). "Moreover, the intensity of magmatic activity increases northward and eastward, although in both directions the Paleozoic rocks of the Sette–Daban Range are obscured by the Carboniferous siliciclastic units of the Verkhoyansk Complex" (Khudoley et al. 2013) and so the full extent could plausibly reach Large Igneous Province (LIP) scale (minimum of 100,000 km^2; Ernst, 2014).

Recent in-situ secondary ion mass spectrometry (SIMS) U-Pb baddeleyite dates (Schmitt et al. 2010; Chamberlain et al., 2010; Khudoley et al. 2013; Chamberlain, unpublished data) coupled with an ID-TIMS U-Pb baddeleyite date (Khudoley et al. 2001), establish that the Suordakh swarm is ca. 450 Ma. The precisions on the existing dates are low enough however, that there could be several discrete magmatic events within the sampled dikes and sills, with additional events ca. 420 Ma and 380 Ma. Ongoing research is focussed on 1) improving the precisions of ages on existing samples from ±10% to ±1% or better, 2) collecting samples from nearby regions to test for the areal extent of the events, and 3) studying the composition and tectonic setting of the Suordakh mafic intrusions.

Higher precisions on the ages of the Ordovician-Silurian mafic intrusions will: 1) determine how many events are present and 2) determine the temporal relationships, if any, between these intrusions and phases of the end-Ordovician extinction.

Results

Six mafic dike and sill samples from Sette-Daban range were collected in 2004 and have preliminary in-situ SIMS U-Pb baddeleyite dates of 457±34 to 379±27 Ma, based on 2 to 8 spot analyses each. Twenty-five or more additional target grains have been identified in each sample using improved mapping techniques. Re-analysis of one sample, X04-14-1, based on 40 new SIMS spots has established a date of 467±18 Ma (Fig. 1), improving both the precision and accuracy on magmatism. The previous date of 379±27 Ma for this sample was based on only 3 analyses, all of which are interpreted to have had some Pb loss discordance based on the new data (Fig. 1).

Twenty-five additional samples were collected in 2017 and 2018 and thin sections are being mapped to determine whether they are dateable. If any of these samples have baddeleyite grains that are >20 microns in size, the baddeleyite will be separated by the Söderlund method (Söderlund and Johansson, 2002), then dated by higher precision, dissolution, isotope dilution, thermal ionization mass spectrometry (ID-TIMS). Preliminary ID-TIMS data from one sample demonstrate more discordance than the corresponding SIMS data however, so resolving the intrusive ages of the Suordakh magmatism may require a combination of dating by both methods.

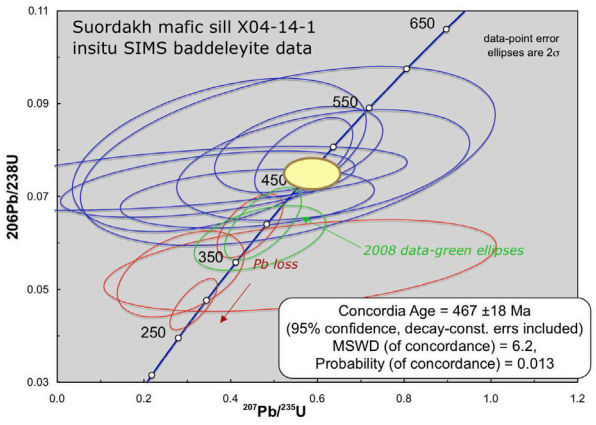

Figure 1. Concordia plot of SIMS spot analyses from Suordakh mafic sill sample X04-14-1 using the CAMECA 1290 at Univ. California at Los Angeles (UCLA), USA. Analyses were from baddeleyite grains (5 to 20 microns in diameter) in polished thin sections using 3x3-micron rastered ion beam spots. The Concordia Age (Ludwig 1998) of 8 high-quality analyses (blue ellipses) is 467±18 Ma (solid yellow ellipse). Data from 4 other spots (red ellipses) are interpreted to reflect varying degrees of Pb loss as they produced a range of younger $^{206}Pb/^{238}U$ dates than the cluster at 467 Ma. The preliminary data collected in 2008 (green ellipses) are also interpreted to reflect Pb loss; the preliminary date from those analyses, 379±27 Ma is now interpreted to be inaccurate. The baddeleyite grains have evidence of post-magmatic alteration to zircon, so data from 40 spot analyses were filtered by Th/U and % radiogenic ^{206}Pb to ensure that the date is based on pure baddeleyite domains.

Conclusions

The end-Ordovician glaciation event and its mass extinction has been an anomaly since it is the sole major mass extinction that is not yet associated with a LIP (Ernst 2014). The temporal link between LIPs and other extinction events is robust. Many major, and some minor, LIP events occur within several million years or less of global extinctions (e.g. Courtillot and Renne 2003; Wignall 2005; Ernst 2014; Bond and Grasby 2016; Ernst and Youbi, 2017). The most compelling examples are currently the Deccan (c. 66 Ma), Central Atlantic Magmatic Province (CAMP; 201 Ma), and the Siberian Trap

(252 Ma) LIPs, whose current dating overlaps precisely in age to the Cretaceous–Tertiary, Triassic–Jurassic, and Permian–Triassic boundary extinctions, respectively (Blackburn et al. 2013; Burgess and Bowring 2015; Schoene et al. 2010, 2015). Improving the age precisions on the Suordakh mafic event will test whether this is the missing LIP for the end-Ordovician extinction.

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CHEMICAL WEATHERING OF LESOTHO HIGHLANDS BASALT

Chen Y.[1], Hedding D. W. [2], Li G-J.[1], Li X-M.[1], Wu W-H.[1]

[1]MOE Key Laboratory of Surficial Geochemistry, Department of Earth and Planetary Sciences, Nanjing University, Nanjing 210023, China
[2]Department of Geography, University of South Africa, Pioneer Avenue, Florida 1710, South Africa
E-mail: chengyang@nju.edu.cn

Basaltic terrains contribute a significant component to the global silicate weathering flux despite its limited areal coverage. A strong correlation between chemical weathering flux and climatic factors such as temperature in volcanically inactive basaltic fields implies that weathering of basalt might have played an important role in maintaining the habitability of the Earth and the balance of the geological carbon cycle. However, the low erosion rate of flood basalt provinces on tectonically quiescent cratons, where the clear climate dependence of weathering rate has been observed, implies a 'supply-limited' weathering regime where weathering flux is controlled by physical erosion rather than climate. This work tests the weathering limitation regime of flood basalts by investigating the weathering flux of the Lesotho Highlands where an extremely low rate of denudation has been registered. Stream chemistry of the rivers in the Lesotho Highlands shows typical characteristics of basalt weathering with Ca and Mg as the dominant cations and HCO_3^- as the dominant anion. Strong spatial and seasonal variability of solute concentration, possibly linked to dilution effect, has been observed. However, the giant Katse reservoir of the Lesotho Highland Water Project effectively averages the spatial and seasonal variability of the solute concentration. The average solution concentration and the long-term runoff monitoring of the Katse catchment give an average atmospheric CO_2 consumption rate of $0.259\pm0.024 \times 10^6$ mol/km^2/yr. The chemical weathering flux requires a minimum chemical alteration rate that is close to the total denudation rate, indicating congruent weathering and thus a 'supply-limited' weathering regime. Nevertheless, the chemical weathering rate of the Lesotho Highlands is still consistent with the global correlation between the rate of basalt weathering and temperature. Rock detachment and thus denudation, controlled by chemical weathering, is suggested to reconcile the paradox between the observed temperature dependence of chemical weathering rate and the 'supply-limited' weathering regime.