Forum Comment

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Formation of high $\delta^{18}O$ fayalite-bearing A-type granite by high-temperature melting of granulitic metasedimentary rocks, southern China

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Huang et al. (2011) describe a granite that they interpret as crystallized from an A-type magma, derived from a metasedimentary protolith. Sun et al. (2011) had already described a similar example, with high initial $^{87}Sr/^{86}Sr$ and low ε_{Nd}. The important question is whether these A-types are necessarily metasedimentary-derived. A-type granites include very high-temperature (*T*) crustal melts and differentiates from tholeiitic to transitional basaltic magmas, contaminated (or not) with crustal material (e.g., Frost and Frost, 1997). It is the lithological character of the source of this magma that we address.

Chief among the reasons for Huang et al. suggesting a sedimentary source are the isotope ratios, with initial $^{87}Sr/^{86}Sr$ of 0.7151–0.7181 and ε_{Nd_T} of –7.36 to –6.61. Considering the Rb and Sr contents of the rocks, the high initial Sr isotope ratio is unlikely to reflect contamination from the wall rocks. We agree that partial melting of an ancient crustal source is their most likely origin. However, this source was not necessarily metasedimentary. Another possibility is that these magmas were derived by high-*T*, fluid-absent melting of older granitoids with crustal isotope signatures. Such a two-stage origin would be compatible with the crustally evolved isotope signature, as well as the high-*T*, A-type character of the rocks and their low volume. Partial melting of a granitoid protolith will yield very small melt proportions, due to the low H_2O content in the biotite and/or amphibole.

Huang et al. suggest a reduced protolith for this granite, to stabilize fayalite. However, any f_{O_2} at or below the fayalite-magnetite-quartz (FMQ) buffer reaction would suffice. In this quartz-saturated, Mg-bearing system, forsterite solid solution in the olivine would significantly raise the f_{O_2} at which fayalite would remain stable. Using a simple ideal model for fayalite-forsterite solution, the Fa_{90} in these rocks would be stable at ~1.4 times the f_{O_2} of FMQ, compatible with a felsic meta-igneous protolith. The authors write that the olivine crystallized early. However, their photograph shows the edge of a large feldspar phenocryst with the adjacent Ol and Opx much finer-grained and intergrown with groundmass quartz and feldspar. Thus, olivine began crystallization relatively late. Since it probably grew at rather low emplacement pressure, it is most unlikely to have been present as a residual phase in the protolith. The f_{O_2} in magmas derived from metasediments typically lies ~10 times lower than FMQ (e.g., Clemens and Wall, 1981), which is why S-type granites are almost all magnetite-free, ilmenite-series rocks. Huang et al. write that the Jiuyishan granite contains ilmenite, but they do not mention magnetite. Thus it seems credible that the protolith for this granite was less oxidized than the sources of many A-type granites, which are magnetite-series. However, this does not constitute clear evidence for a metasedimentary source, as remelting of an ilmenite-series granitoid source would produce the same result.

Southeastern Australian I-type rocks have initial $^{87}Sr/^{86}Sr$ ratios of 0.7045–0.71189 and ε_{Nd_T} of –8.9 to +0.4. These Chinese rocks have only slightly more radiogenic Sr than classical I-types and ε_{Nd_T} well within the I-type range. This could signify that the meta-igneous source rocks for these Chinese granites were of significant antiquity—Mesoproterozoic or older, as suggested by model ages calculated from the zircon Pb and whole-rock Nd isotopes. Alternatively, the protoliths could have been Early Palaeozoic felsic igneous rocks, themselves formed from magmas generated from more ancient crust. Indeed, the South China Block contains large volumes of Early Palaeozoic, crustally derived granites. Magnetite-series I-type granites can have whole-rock $\delta^{18}O$ up to 10.8‰ (e.g., Anderson and Morrison, 2005). Thus, the $\delta^{18}O$ values in the zircons of the Jiuyishan granite (equivalent to whole-rock values of 9.5–11.6) do not firmly support a metasedimentary source. Indeed, S-type granites, which *do* have metasedimentary protoliths, have minimum $\delta^{18}O$ values of 10‰.

Felsic magmas derived from metasedimentary sources are strongly peraluminous, irrespective of their formation temperature; no amount of fractionation can change this. The Jiuyishan rocks are metaluminous to weakly peraluminous, similar to many I-type suites, which only become metaluminous at relatively low SiO_2. For comparison, Clemens et al. (2011) describe very high-*T*, metasediment-derived S-type volcanic rocks (with fayalite microphenocrysts) and extreme enrichment in Zr. These rocks are very strongly peraluminous and contain highly aluminous phenocrysts such as garnet and cordierite.

From the evidence presented, we conclude that the Jiuyishan granite is a high-*T*, A-type granite magma that formed by partial melting of a somewhat older, felsic, meta-igneous protolith with a crustal isotope signature. Thus, the source of the Jurassic A-types of the South China Block was probably dominated by igneous rocks. Misidentification of probable source rocks for granites could have serious implications for the interpretation of subsurface geology in a region.

REFERENCES CITED

Anderson, D.L., and Morrison, J., 2005, Ilmenite, magnetite, and peraluminous Mesoproterozoic anorogenic granites of Laurentia and Baltica: Lithos, v. 80, p. 45–60, doi:10.1016/j.lithos.2004.05.008.

Clemens, J.D., and Wall, V.J., 1981, Crystallization and origin of some peraluminous (S-type) granitic magmas: Canadian Mineralogist, v. 19, p. 111–131.

Clemens, J.D., Birch, W.D., and Dudley, R.J., 2011, S-type ignimbrites with polybaric crystallisation histories: The Tolmie Igneous Complex, Central Victoria, Australia (and erratum): Contributions to Mineralogy and Petrology, v. 162, p. 1315–1337 and 1339, doi:10.1007/s00410-011-0652-1 and 10.1007/s00410-011-0666-8.

Frost, C.D., and Frost, B.R., 1997, Reduced rapakivi-type granites: The tholeiite connection: Geology, v. 25, p. 647–650, doi:10.1130/0091-7613(1997)025<0647:RRTGTT>2.3.CO;2.

Huang, H.-Q., Li, X.-H., Li, W.-X., and Li, Z.-X., 2011, Formation of high $\delta^{18}O$ fayalite-bearing A-type granite by high temperature melting of granulitic metasedimentary rocks, southern China: Geology, v. 39, p. 903–906, doi:10.1130/G32080.1.

Sun, Y., Ma, C.Q., Liu, Y.Y., and She, Z.B., 2011, Geochronological and geochemical constraints on the petrogenesis of late Triassic aluminous A-type granites in southeast China: Journal of Asian Earth Sciences, v. 42, p. 1117–1131, doi:10.1016/j.jseaes.2011.06.007.