Isotopic Heterogeneity and Potential Variable Sources of Granitic Rocks of the Sebago Migmatite Domain, Southern Maine

Paul Tomascak & Maxwell Grade,
SUNY-Oswego

and **Gary Solar,**
SUNY College at Buffalo

History of Granitic Rocks of the Sebago Area

At the time of the production of the 1985 Bedrock Geologic Map of Maine, the granitic rocks around Sebago Lake were grouped under the blanket heading of the Sebago Batholith, comprising, in terms of map area, the largest igneous body in New England. Subsequent investigations began to reveal problems with this omniclusive model for these rocks. More recent mapping and laboratory studies define, as might be expected, a greater degree of complexity and hence greater demand for integrated studies of structure, petrology and geochemistry to clearly define the nature of these rocks.

We now recognize a single, texturally and geochemically more homogeneous, two-mica granite pluton (the Sebago pluton; Fig. 1) centered approximately on Sebago lake. Surrounding the pluton on the west, north and east sides is a broad region dominated by migmatitic rocks of variable texture and interspersed with granitic bodies ranging in scale from cm through tens of m. This regional is collectively referred to herein as the Sebago Migmatite Domain (SMD). Part of the thrust of this study is drawn comparisons between the Sebago pluton and granitic rocks within the SMD in order to better understand their petrogeneses.

Geochronology in the Sebago Area

Aleinikoff et al. (1985) estimated ages from large zircon populations from two Sebago samples. These discordia defined an apparent upper intercept age of 325 ± 3 Ma. This age was problematical given regional K-Ar ages from minerals in metamorphic country rocks and granitic rocks. Subsequently, Tomascak et al. (1996) produced a nearly concordant U-Pb age of 293 ± 2 Ma from a multigrain fraction of monazite.

Crystallization age relations within the Sebago Migmatite Domain remain undetermined, although work is under way in our group toward this end. Ongoing geochronologic studies of zircon from rocks on the eastern margin of the Sebago pluton using LA-MC-ICP-MS to define target samples for single-grain TIMS work, have found ages clustering around 305 Ma (Tomascak et al., 2008), although a population of younger (c. 285 Ma) grains occur in one medium-grained two-mica granite sample. Additional ongoing geochronological work will employ TIMS methods to select grains from samples in both the eastern and western SMD (e.g., Figure 2).

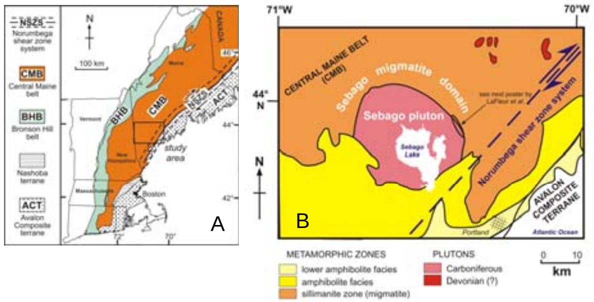

Figure 1. Location of the study area in southern Maine (A). The area is bounded on the southeast by the Norumbega Shear Zone system, which, in the area of (B) is a wide zone of distributed ductile deformation. Although quantitative petrology is inhibited by quartzofeldspathic lithologies of much of the surrounding metasedimentary rocks, migmatite-dominant outcrop suggests a broad region of upper amphibolite facies or higher grade conditions. Note the reference to the adjacent poster by L. LaFleur.

The Contribution of Pb Isotopes to This Work

Initial isotopic compositions of Pb in low-U minerals such as alkali feldspar have proven valuable for assessment of basement courses for granitic rocks in the Appalachian orogen (Ayuso and Bevier, 1989; Samson et al., 1995; Whalen et al., 1996). In particular, the ratio $^{207}Pb/^{204}Pb$ is of great potential utility, as it is insensitive to U-Pb variations in crustal sources during the last 2+ Ga, and records only variations derived from Archean fractionation events.

Whereas Nd isotopes are geologically robust, in this area they cannot by themselves be used for crustal source discrimination (Fig 5). However, when $^{207}Pb/^{204}Pb$ is compared to initial Nd isotopes, a more diagnostic probe of granitic sources may be achieved (Fig. 6). Nevertheless this is not a perfect instrument for source fingerprinting, as the end member compositions are not presently unambiguously characterized.

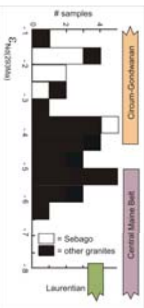

Figure 5. Histogram of Sebago area granite initial Nd isotopes, inscribed with some of the better-characterized regional crustal components.

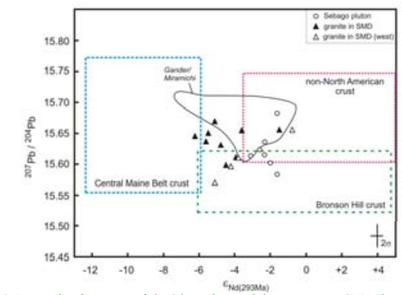

Figure 6. Isotopic data for granites of the Sebago pluton and the encompassing SMD. The interpretation of Tomascak et al. (1996) for a more limited group of Sebago area rocks considered homogeneous, deeper-sourced Sebago pluton melts mixing with melts derived from anatexis of mid-crustal (Central Maine Belt) rocks to produce the more heterogeneous granites of the SMD. Data from the present and other more recent studies permit the western granites to be derived from sources unlike those that produced the Sebago pluton. Fields are estimated source signatures based mainly on unpaired Nd-Pb isotope samples from many literature sources (see Tomascak et al., 2005).

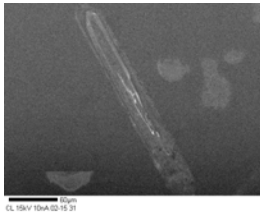

Figure 2. Cathode luminescence image of typical zircon from western SMD granite sample 02-15 (from C.P. Kauffman undergraduate research, SUNY-Oswego, image collected at the Earth Sciences Dept. at Syracuse University). Scale bar is 0.06 mm. Grains show concentric CL zonation, indicative of undisturbed igneous crystallization.

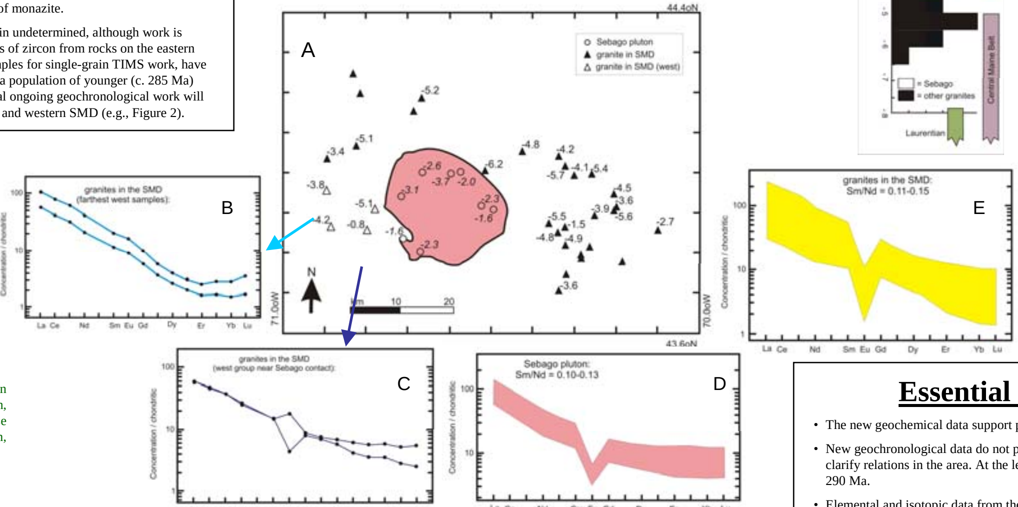

Figure 4. A. Initial Nd isotopic compositions (ε @ 293 Ma) of Sebago area granites. Note the homogeneity in Nd isotopes and in REE (D) for the Sebago pluton samples, compared to samples from the SMD. The four samples from the western part of the SMD are split out because of variations in Nd isotopes and lanthanide abundances.

Geochemistry of Sebago Area Granites

Granitic rocks of the area are all peraluminous and silica-rich. The granites of the Sebago pluton are texturally the most uniform two-mica granites of the region. Granites in the SMD are predominately biotite granites, very commonly with igneous foliation and biotite-enriched schlieren. Rocks with pegmatitic and aplitic textures are common, and dominate in some outcrops.

The mineralogical and textural distinctions translate to resolvable elemental differences, as seen in Figure 3. Although the Si-rich nature of the samples precludes application of simple liquid line of descent modeling, trace elements such as the lanthanides (Fig. 4 B-E) demonstrate that some western SMD samples are not compatible with derivation from sources like those that produced the Sebago pluton.

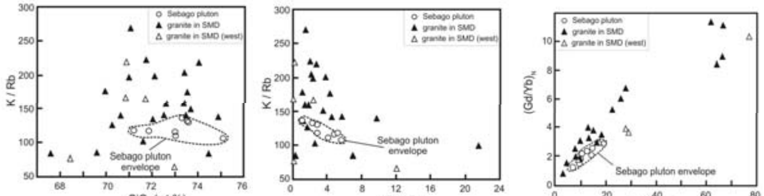

Figure 3. Summary of the elemental geochemistry of Sebago area granites. In all cases the scatter among Sebago pluton samples is minimal compared to that of granites within the SMD.

Essential Findings and Ongoing Work

- The new geochemical data support previous interpretations concerning the nature of the Sebago pluton (c. 400km^2).
- New geochronological data do not preclude earlier petrogenetic interpretations, although more data are needed to clarify relations in the area. At the least, these data indicate a sustained period of granite magmatism between c. 305 & 290 Ma.
- Elemental and isotopic data from the granitic rocks in the western part of the Sebago Migmatite Domain are sufficiently deviant from the other Sebago area granites as to preclude a single source-mixing model. The initial Nd-Pb isotope compositions permit the western samples to represent mixtures of a Sebago-like component (derived from non-North American lower crust, e.g., Avalon Composite Terrane) and a component with lower time-averaged U/Pb, resulting in lower $^{207}Pb/^{204}Pb$.

Mike Kalczynski's talk at this meeting (Friday 9:40, Grand Ballroom EF) will detail the migmatitic envelope of the western margin of the Sebago pluton, the area the geochemically more anomalous samples from this study originate.

The undergraduate research of Claire Kauffman deals with the geochronology of some of these rocks, including the zircon from Figure 2. If you are interested, she will be presenting her results at the GAC-MAC meeting on her results in Québec City in late May.

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References Aleinikoff et al. (1985) Contributions to Mineralogy and Petrology 96, 990-996; Ayuso and Bevier (1991) Tectonics 10, 191-212;Samson et al. (1995) Earth and Planetary Science Letters 134, 359-376; Tomascak et al. (2008) Geological Association of Canada-Mineralogical Association of Canada Abst; Tomascak et al. (2005) Lithos 80, 75-99; Tomascak et al. (1996) Contributions to Mineralogy and Petrology 125, 45-59; Tomascak et al. (1996) Journal of Geology 104, 1858-195; Whalen et al. (1996) Canadian Journal of Earth Sciences 33, 129-139.