Spatial variability of biologically available $^{87}Sr/^{86}Sr$, rare earth and trace elements in the Cis-Baikal region, Siberia

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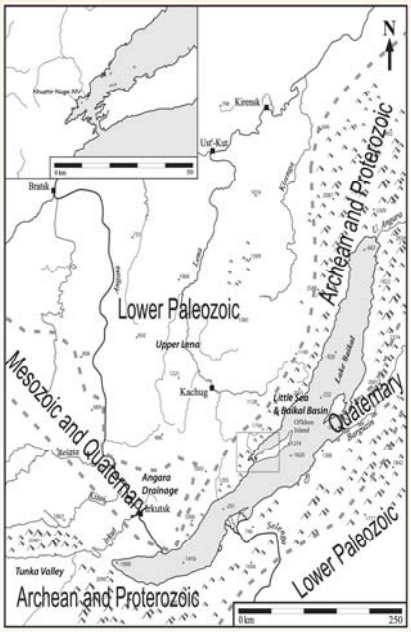
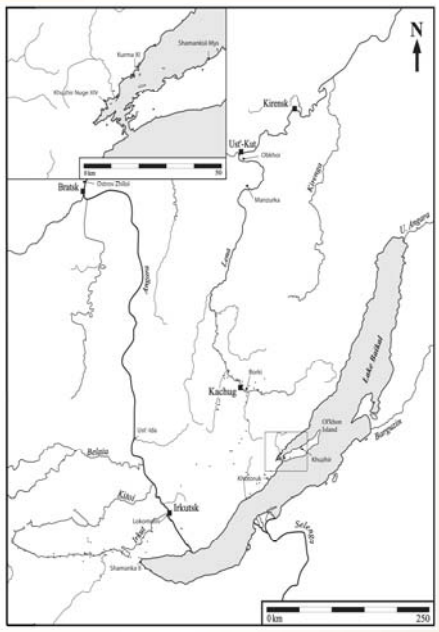


Lake Baikal, Siberia showing the age of the dominant bedrock formations and the location of the Khuzhir Nuge XIV cemetery used in previous mobility studies

Background

Previous geochemical studies in the Cis-Baikal region have indicated that regional $^{87}Sr/^{86}Sr$ ratios effectively follow the dominant bedrock geology (Haverkort et al. 2008). The study region can subdivided into three major geologic zones. The area along the west coast of the lake is dominated by Archean and Proterozoic granites (~0.720-0.735 expected).. Similar bedrock occurs on the southwest coast of the lake and the drainages from the eastern Sayan Mountains including the drainage basin of the Tunka region. The upper section of the Angara flows through Mesozoic and Quaternary deposits (~0.705-0.710 expected). The upper Lena watershed forms part of the Central Siberian Pleateau, and is dominated by Cambrian and Precambrian limestone (0.709 expected). The lake itself has values of ~0.7085-0.7089.

As these main geologic zones roughly correspond with three main archaeological micro-regions: (1) the Baikal basin including the Little Sea and Ol'khon Island; (2) the drainage of the middle and upper Angara River; and (3) the upper Lena Basin; there is great potential for geochemical variability useful for mobility studies in the region. However, the extent to which hypotheses regarding hunter-gatherer mobility can be tested with geochemical data depends heavily on our understanding of the full range of variability possible in the region. $^{87}Sr/^{86}Sr$ ratios reflect the dominant bedrock geology but limit potential provenance determination and interpretation to large geologic zones. Preliminary results of the tandem use of $^{87}Sr/^{86}Sr$ and elemental data in mobility studies have been promising and provide an avenue for refinement of current methodologies.

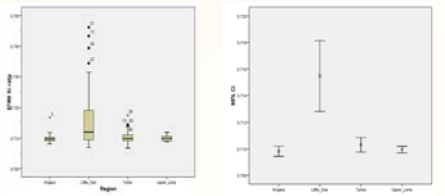


Sampling locations indicated by (•). Named locations denote cemeteries used in ongoing mobility research.

Methodology

Assessment of biologically available $^{87}Sr/^{86}Sr$ and elemental data was conducted using a combination of faunal, plant and water samples. Faunal materials consisted of modern bone and tooth samples, processed and analyzed using laboratory protocols for solution preparation of archaeological materials. Dried plant materials were ashed in a muffle furnace prior to solution preparation. Water samples were concentrated and analyzed as solutions. Analyses were conducted at the Radiogenic Isotope Facility in the Department of Earth and Atmospheric Sciences, University of Alberta. Elemental analysis was conducted using a Perken Elmer Elan6000 quadrupole ICP-MS. Isotopic analysis was performed using a Nu Plasma multicollector ICP-MS coupled with a DSN-100.

Further analysis of 43 molar samples reflecting 16 individuals from 6 of the smaller cemeteries in the Cis-Baikal region, were analyzed for elemental composition using laser ablation quadrupole ICP-MS. Each molar reflects several years of growth, so each tooth was sampled at 4 points between the crown and the cingulum. The exact relationship between uptake, depositional and mineralization of tooth enamel is still unclear, however, given the span of time reflected by each tooth, 4 evenly spaced sampling locations should reflect ~6-10 months of temporal separation between final mineralization.

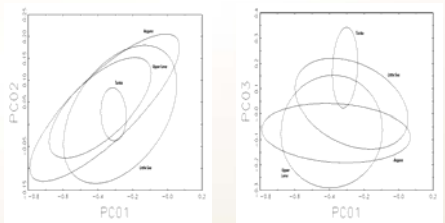


(Left) Boxplot with regional range and mean. (Right) 2 sigma confidence interval bar graph.

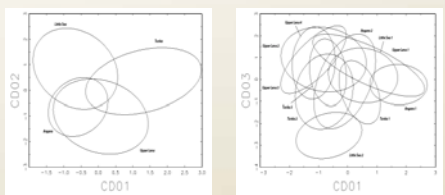
Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Angara	50	.00869	.70811	.71680	.7098178	.00136677	.000
Little_Sea	76	.04531	.70694	.75225	.7160494	.00994818	.000
Tunka	58	.01075	.70673	.71748	.7101367	.00184106	.000
Upper_Lena	52	.00310	.70881	.71191	.7099700	.00085673	.000
Valid N (listwise)	50						

Descriptive statistics for $^{87}Sr/^{86}Sr$



Principal components analysis for regional groups using $^{87}Sr/^{86}Sr$ and elemental data.



Discriminant function analysis for regional groups (left) and subgroups (right) showing that no clear distinctions can be made using these groups.

Results

In spite of promising preliminary results, the range of variability observed in the $^{87}Sr/^{86}Sr$ data was astounding. Rather than effectively mimicking bedrock geology with some attenuation for translating bedrock geology to biologically available Sr, there was a confounding overlap in the ranges of $^{87}Sr/^{86}Sr$ values through all regions. Furthermore, even groups of similar aged geologic formations (Archean and Proterozoic zones along the western coast and Tunka regions) exhibited different $^{87}Sr/^{86}Sr$ values. Regional groups did exhibit different ranges and means, however the extent of overlap renders moot much discussion of mobility and provenancing. The clear exception to this overlap is the Little Sea region where distinctly higher $^{87}Sr/^{86}Sr$ values would and do make apparent any contact with bioavailable Sr from this region. Previous work had indicated a spike in both terrestrial and aquatic $^{87}Sr/^{86}Sr$ values associated specifically with the Sarma drainage adjacent to Khuzhir Nuge XIV, however this effect appears to be more widespread through the micro-region. The consequences of this effect are visible in the graph of the mean and 2 sigma confidence intervals for regional $^{87}Sr/^{86}Sr$ values.

Due to the complexity of the situation, multivariate statistical approaches were attempted to enable group discrimination. Principal component analysis and discriminant function analysis were attempted, on regional groups reflecting the Middle Angara, Tunka, Baikal coast/Little Sea, and the upper Lena regions. Following this, regional groups were subdivided into 2-4 groups each based on combinations of $^{87}Sr/^{86}Sr$ and elemental values for a total of 11 subgroups.

Given the failure of source group discrimination, serious provenancing efforts for the human molars was not attempted. Preliminary examination indicated a strong affinity for the upper Lena, however it is unclear whether this is an artifact of the data with the current source group definitions or not.

Conclusions

Greater than expected variability in all regional groups hindered efforts at establishing effective source groups for the comparison and provenancing of biological materials in the Cis-Baikal region. Future work will focus on the establishment of valid geographical/geochemical groups that may not neatly mirror archaeological micro-regions but will be effective chemical groupings.

Works Cited
Haverkort, C. M., A. Weber, et al. (2008). "Hunter-gatherer mobility strategies and resource use based on strontium ($^{87}Sr/^{86}Sr$) analysis: a case study from Middle Holocene Lake Baikal, Siberia." Journal of Archaeological Sciences **35: 1265-1280.**