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Turquoise Mine and Artifact Correlation for Snaketown Site, Arizona

Abstract. *Trace element analyses on turquoise from 24 mines in the southwestern United States indicate that the turquoise artifacts from Snaketown site in south-central Arizona came from the Himalaya mine near Halloron Springs, California. The correlation of artifact and mine turquoise in the Southwest is a means of determining prehistoric exchange patterns.*

Turquoise artifacts are found in archeological sites throughout the southwestern United States. The geographic distribution of the mineral, however, is limited to the margins of the Colorado Plateau in Arizona, New Mexico, and Colorado, and to a group of mines trending northeast in Nevada. Trace element analyses of turquoise (*1*) have demonstrated significant differences between individual localities (*2*). By means of trace element techniques, it is thus possible to identify the source of the mineral by comparing the trace element content of the artifact with that of turquoise from established geologic sources. The identification of source areas for archeological sites will provide needed information on the nature of prehistoric procurement systems and aid in defining exchange routes.

Thirteen turquoise beads from Snaketown site and multiple samples from each of 24 turquoise mines (Fig. 1) in the Southwest were analyzed by instrumental neutron activation analysis (INAA) in order to determine the source of the Snaketown turquoise. Trace element patterns for each of the beads were compared and found to be similar, suggesting a single source area for all of the beads. The trace element patterns for the beads correlated with that of turquoise from the Himalaya group of mines near Halloron Springs, California, but not with data from the other mines analyzed. This correlation was unexpected since there are several turquoise mines with prehistoric workings geographically closer to Snaketown (*3*).

Snaketown site is a 121-hectare village of single-unit dwellings occupied by the pre-Columbian Hohokam culture group from the beginning of the Christian Era until A.D. 1200. The village is situated on the Gila River Indian Reservation 20.9 km southwest of Chandler, Arizona. Excavations in 1936 and 1964 to 1965 revealed numerous house floors, wells, cremations, and platform mounds along with an abundance of ceramic and artifact material (*4*). The earliest turquoise artifacts known for the Southwest were found at Snaketown. The disk-shaped beads analyzed by INAA were found in the fill of house 8, which was occupied during the Gila Butte Phase (A.D. 500 to 700) of the site.

The Himalaya group of mines, 8 km northeast of Halloron Springs, California, have evidence of extensive prehistoric activity. The prehistoric workings consist of saucer-shaped pits up to 10 m across and 2 m deep. Stone tools were common in the pits, and nearby caves had fire-blackened ceilings, tools, and pottery fragments with incised designs. Rock carvings have been noted on basalt cliffs and boulders in the vicinity (*5*).

Trace element analysis of geologic materials by the INAA method has been described (*6*). Prior to analysis, geologic samples were coarsely crushed, and fragments of turquoise were hand-picked from matrix material under a petrographic microscope. Artifacts were thoroughly washed in an ultrasonic cleaner before irradiation to eliminate surface contaminations. The 13 beads varied in color from light blue to dark blue-green, and weighed between 100 and 300 mg.

The samples were subjected to a series of 1-minute and 6-hour irradiations in the University of Arizona TRIGA reactor in a neutron flux of 10^{12} neutrons cm^{-2} sec^{-1}. The resultant activity was counted on a 55-cm^3 (9.6 percent efficiency) Ge(Li) semiconductor detector connected to a 4096-channel analyzer after the appropriate periods of decay. The turquoise samples were analyzed by comparison with specific activities produced in synthetic turquoise standards activated at the same time. U.S. Geological Survey standard rock GSP-1 was used to check the analytical procedure (*7*).

INAA proved to be a valuable technique for detecting significant differences in trace element concentrations of turquoise from different geographic localities. Co, Cr, Eu, Sb, Sc, and Ta were most useful in this correlation despite the fact that 30 elements were investigated for each sample. Values for Au, Ba, La, Lu, and Fe were not particularly diagnostic since they varied as much within mines as between them. The concentrations of most trace elements in the Himalaya and Snaketown samples were low, relative to concentrations in samples from other areas. Specifically, the values for both Co and Cr clustered between 1 and 2 ppm for the Himalaya-Snaketown samples, while the range in the 23 other mines was 8 to 1000 ppm for Co and 18 to 260 ppm for Cr. Concentrations of Mn, V, Ag, Rb, Sn, Nd, Tb, Yb, Zr, Ta, Hf, and W were below the analytical detection

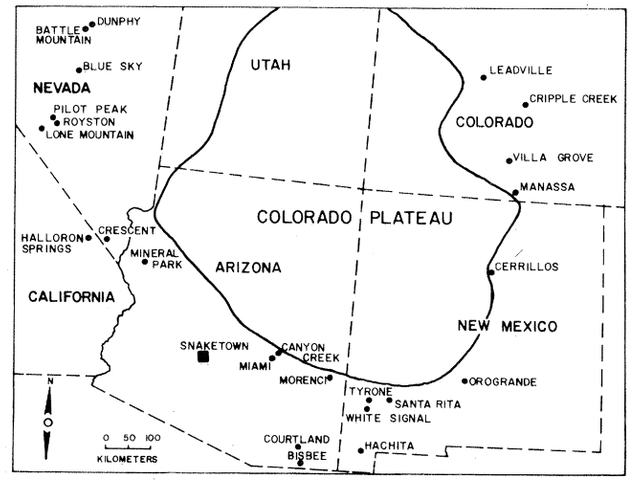

Figure 1. Location of turquoise mines and Snaketown site.

Table 1. Data for the determination of the turquoise bead source area; ppm, parts per million.

Element	Snaketown			Himalaya		Crescent
	Group A	Group B	Unclassified	Group A	Group B	
			Trace element data (ppm)			
Co	1.67	1.78	1.95	1.30	1.78	1003.0
Cr	1.66	1.44	1.20	1.54	2.30	67.3
Eu	0.26	0.32	0.28	0.27	0.63	*
Sb	2.10	2.90	1.43	1.76	2.10	4.66
Sc	35.1	101.5	15.1	36.2	106.4	65.3
Ta	*	*	*	*	*	326.0
			Similarity coefficients			
Snaketown						
Group A	1.000					
Group B	.825	1.000				
Unclassified	.544	.337	1.000			
Himalaya						
Group A	.946	.808	.613	1.000		
Group B	.861	.991	.565	.840	1.000	
Crescent	.143	.177	.092	.208	.101	1.000

*Not detected.

limits for the Himalaya-Snaketown turquoise, but were present in many of the other samples. These basic differences served to distinguish the California source area from other localities by simple examination of the data.

The Snaketown beads fell into two groups of five and seven samples each, based on Sc contents of 35 ppm (group A) and 100 ppm (group B), with 1 sample unclassified. The data for samples from the Himalaya mine also fell into the same two groups, emphasizing the need for multiple samples from each geographic source area.

In order to characterize the mine areas statistically, it was necessary to compare the concentrations of all trace elements simultaneously. The multivariate statistic devised by Borchardt *et al.* (*8*), in which the ratio of each element concentration in a pair of samples is summed and divided by the number of elements, was found to be the most useful for these data (*9*). The coefficients thus obtained are representative of the degree of similarity, or dissimilarity, between two or more samples. That is, the coefficients are a means of quantifying the degree of correlation based on sample analytical data. Perfect similarity results in a value of 1.0, and large differences result in coefficients near zero. Borchardt *et al.* determined by replicate analyses that coefficients above .800 were indicative of an accurate correlation at the 95 percent confidence level. Conversely, values below .560 indicated that a pair of samples probably were not from the same site.

Table 1 shows the correlation coefficient matrix for the two Snaketown groups, the unclassified bead, the two Himalaya mine groups, and for the Crescent mine in Nevada. On the basis of Borchardt's criterion, there is good correlation between samples from Snaketown A and Himalaya A, and between Snaketown B and Himalaya B. The Crescent sample is clearly unrelated.

The similarity coefficients, then, substantiated the conclusion that trace element patterns for the Snaketown beads correlated with that of turquoise from the Himilaya group of mines near Halloron Springs, but not with the data from the 23 other mines analyzed. The 13 turquoise beads, however, represent only a portion of the turquoise from the site. Since turquoise was widely traded in the Southwest, it is possible that other sources may by represented in other artifacts from Snaketown.

Cultures and cultural ties are constantly changing, and it is expected that trade patterns will also change with time because of political and economic pressures, or the depletion of a resource procurement area. Chemical analysis of a commonly utilized material such as turquoise is one method of detecting, or monitoring, these changes. Further identification of source areas utilized by particular cultural groups should provide additional information on the nature of prehistoric resource acquisition and exchange routes.

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10. The similarity coefficient
$$d_{ab} = \sum_{1}^{n} R_i/n$$
where $R_i = X_{ia}/X_{ib}$ if $X_{ib} \geq X_{ia}$; or X_{ib}/X_{ia} if $X_{ia} > X_{ib}$; X_{ia} = the content of element i in sample a; X_{ib} = content of element i in sample b; and n = the number of elements.

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Climatic Change: Are We on the Brink of a Pronounced Global Warming?

Abstract. *If man-made dust is unimportant as a major cause of climatic change, then a strong case can be made that the present cooling trend will, within a decade or so, give way to a pronounced warming induced by carbon dioxide. By analogy with similar events in the past, the natural climatic cooling which, since 1940, has more than compensated for the carbon dioxide effect, will soon bottom out. Once this happens, the exponential rise in the atmospheric carbon dioxide content will tend to become a significant factor and by early in the next century will have driven the mean planetary temperature beyond the limits experienced during the last 1000 years.*

The fact that the mean global temperature has been falling over the past several decades has led observers to discount the warming effect of the CO_2 produced by the burning of chemical fuels. In this report I present an argument to show that this complacency may not be warranted. It is possible that we are on the brink of a several-decades-long period of rapid warming. Briefly, the argument runs as follows. The ^{18}O record in the Greenland ice core (*1*) strongly suggests that the present cooling is one of a long series of similar natural climatic fluctuations. This cooling has, over the last three decades, more than compensated for the warming effect produced by the CO_2 released into the atmosphere as a by-product of chemical fuel combustion. By analogy with similar events in the past, the present natural cooling will, however,