Was Aztec and Mixtec Turquoise Mined in the American Southwest?

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**Recommended Citation**

Thibodeau, Alyson M., Leonardo López Luján, David J. Killick, Frances F. Berdan, and Joaquin Ruiz. "Was Aztec and Mixtec Turquoise Mined in the American Southwest?" *Science Advances* 4, no. 6 (2018): eaas9370. http://advances.sciencemag.org/content/4/6/eaas9370

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INTRODUCTION
For more than 150 years, scholars have argued that Mesoamerican societies imported turquoise from the American Southwest or adjacent parts of northwestern Mexico—a region that many archaeologists refer to as the Greater Southwest (1–7). Turquoise [CuAl₆(PO₄)₄(OH)₈·4H₂O] was one of several blue-green minerals highly valued by prehispanic societies across both regions, including the Aztec, Toltec, Maya, Mixtec, and Tarascan states in Mesoamerica, and the Hohokam, Mogollon, and Puebloan groups of the Greater Southwest (hereafter “Southwest”). Although turquoise artifacts are found in archaeological sites throughout these regions, major North American turquoise deposits and prehispanic turquoise mines are largely confined to the U.S. states of Arizona, New Mexico, California, Colorado, and Nevada and to parts of northernmost Mexico (Fig. 1) [(8) and references therein].

The observation that there are numerous known examples of prehispanic turquoise mines in the Southwest, but not in Mesoamerica, has, in part, formed the basis for claims that Mesoamerican groups imported turquoise from the north (7). The long-distance exchange of ideas and other items between Mesoamerican and Southwestern groups is well documented, especially after ~900 CE, when firms evidence for small quantities of Mesoamerican imports (for example, scarlet macaws, cacao, and copper bells) appears in Southwestern archaeological sites (9–11). Many archaeologists have suggested that turquoise was traded to Mesoamerica in exchange for these exotic goods. In addition, assertions about sources of Mesoamerican turquoise also derive from previous geochemical investigations. From the 1970s through the 1990s, there was a long-term program of chemical analysis by neutron activation of both Mesoamerican and Southwestern turquoise objects (2–5). These studies interpret the geologic provenance of various turquoise artifacts by comparing their trace and major element signatures with those of turquoise samples from prehispanic mines. Although the resulting publications claim that turquoise artifacts from Mesoamerica derive from Southwestern mines (2–5), the underlying data were never published. Thus, their assertions that Mesoamerican societies acquired turquoise from the Southwest cannot be evaluated.

Here, we revisit the hypothesis that Mesoamerican turquoise derives from the Southwest by using lead (Pb) and strontium (Sr) isotopes as tools to investigate the geologic origin of turquoise objects associated with the Aztecs and Mixtecs. In the Basin of Mexico, Aztec (Mexico) elites were among the most prolific consumers of turquoise during the Aztec imperial years of the Late Postclassic (ca. 1430 to 1519 CE). Turquoise figures prominently in Aztec poetry, ritual, and cosmology (12–15) and was used to make a variety of mosaic objects (for example, ceremonial shields, handles on sacrificial knives, mirrors, diadems, pectorals, armbands, necklaces, noseplugs, and earrings) that were worn or wielded by rulers, priests, or other high-status individuals in Aztec society (16–20) and even decorated wolves and other sacred animals (21). Our knowledge of xihuitl (or turquoise) in the Aztec empire primarily derives from 16th century documents and codices that contain textual and pictorial representations of the mineral (17–19, 22). According to the Codex Mendoza, an imperial tribute list, turquoise was sent to the Aztec imperial overlords from two provinces in the southern (Mixteca) area of the empire and from one province in the empire’s northeastern corner (Fig. 1) (22). Extant examples of Mesoamerican turquoise mosaics include about two dozen Mixe- and Mixteca-style mosaics that reside in European and American museums and have no archaeological provenience (fig. S1) (16, 23–25). There are also a number of archaeologically recovered artifacts, including Mixtec turquoise mosaics directly excavated from Monte Albán’s Tomb 7 (26) and Mexican mosaics from buried offerings within the Sacred Precinct of Tenochtitlan (figs. S2 to S4 and table S1) (21, 27–29), which was the political and ceremonial center of the Aztec empire (Fig. 1) (27, 30).

Background
Presently, there are Pb and Sr isotopic measurements of both geological and archaeological samples of turquoise from the Southwest that provide a baseline for evaluating whether Aztec or Mixtec artifacts have a Southwestern origin (8, 31–33). These measurements include Pb and Sr isotopic ratios on >150 geological samples of turquoise from 19 different mining districts across Arizona, New Mexico, Colorado, southeastern California, and southern Nevada in the United States, and in northern...
The Southwestern turquoise deposits shown here are discussed in the study of Thibodeau et al. (8) and have been previously characterized with Pb and Sr isotopic ratios (8, 31, 33). No isotopic data are available on turquoise deposits of the Concepción del Oro or Mazapil localities. Aztec tributary provinces are drawn based on the study of Berdan (18). Dotted red line indicates approximate boundary between the Aztec and Tarascan empires.
Sonora, Mexico (8, 31). Many of the geological samples derive from mining districts with known prehispanic mining activity.

Unlike the Southwest, where there are many documented prehispanic turquoise mines with associated isotopic data, little is known about possible turquoise deposits within the Aztec empire, including the Mixteca region, or in other bordering areas of Mesoamerica. In Mexico, the southernmost turquoise mines that have been documented in both the geological and archaeological literature are near the municipalities of Concepción del Oro and Mazapil in northern Zacatecas (2, 7, 34). Some of the older archaeological and ethnohistorical literature preserves second-hand reports of turquoise deposits in Jalisco and Puebla (18, 35, 36), but, to the best of our knowledge, no scholars have located or verified the existence of turquoise deposits in these areas. However, because turquoise mines are often small and shallow workings occurring near economically significant deposits of copper, they may be easily exhausted, altered, or destroyed by later mining practices. The destruction of ancient turquoise mines is known to have occurred in the American Southwest [for example, see discussion in the study of Thibodeau et al. (33)] and thus may have also occurred in Mexico as well.

Although we are not aware of any direct evidence for turquoise mineralization in Mesoamerica, Pb and Sr isotopes offer an indirect approach to evaluating the possibility that Mesoamerican turquoise artifacts derive from Mesoamerican sources. To understand how, it is useful to first consider Pb and Sr isotopic variation in Southwestern turquoise deposits. Turquoise is generally formed in the oxide zones of copper deposits and derives its elemental constituents from the weathering of the surrounding geologic formations. In the Southwest, the isotopic characteristics of turquoise deposits vary regionally and reflect broad-scale differences in the age, chemical composition, and sources of the associated rocks (8, 37). For example, in Arizona and New Mexico, many turquoise deposits have Pb isotopic signatures that broadly mirror those of their host copper porphyry deposits and associated felsic igneous complexes. In turn, these porphyry deposits have Pb isotopic characteristics that are consistent with the crustal province in which they are located, which is controlled by the age, initial Pb isotope composition, and U/Pb and U/Th ratios of the Proterozoic crystalline basement rocks that underlie southwestern North America (38). Strontium isotopic ratios of turquoise deposits also vary regionally in the Southwest: Deposits that have formed in the weathering zones of Laramide-age copper porphyry deposits or that are hosted by outcropping Precambrian rocks (for example, in central and southern Arizona) tend to have more radiogenic Sr isotopic ratios ($^{87}\text{Sr}/^{86}\text{Sr}$ range, ~0.709 to 0.845) than deposits that have formed from the weathering of Oligocene copper-gold porphyry deposits in the Rio Grande Rift Valley of New Mexico and Colorado ($^{87}\text{Sr}/^{86}\text{Sr}$ range, ~0.707 to 0.709) (8). Because turquoise deposits with similar isotopic signatures tend to cluster geographically based on the underlying geology, it should be possible to infer the region from which an artifact derives even if it has isotopic signatures that do not match a known deposit. Thus, Pb and Sr isotopes can potentially provide insight into the provenance of turquoise objects even if they derive from deposits that have been destroyed, are not known, or have not been sampled.

As is the case in the Southwest, we assume that any turquoise deposits present in Mesoamerica would form in the oxide zone of copper deposits and inherit their Pb and Sr isotopic signatures from the weathering of surrounding ores and rock units. Thus, existing data on the Sr isotope geochemistry of felsic rocks associated with copper ores in Mexico (39–41) provide a baseline for predicting whether and how the Sr isotopic compositions of any putative Mesoamerican turquoise deposits would differ from Southwestern ones. Likewise, abundant published data on the Pb isotopic ratios of copper and other mineral deposits in Mexico (42–45) provide a baseline for predicting the Pb isotopic characteristics of any turquoise deposits that may exist or may have once existed in this region.

**Samples**

We analyzed a total of 43 turquoise mosaic tiles, 38 of which were excavated from offerings in Tenochtitlan’s Sacred Precinct, mainly within the Templo Mayor (Table 1) (21, 26–28). Offerings containing turquoise artifacts are primarily located in the southern half of the Templo Mayor (fig. S3 and table S1) and are related to the cult of the Aztec patron god Huitzilopochtli, a war and sun deity. This southern half is also symbolically connected with Xiuhchecuhiti, the Turquoise Lord and fire deity. Most of the artifacts analyzed for this study derive from offerings that date to the late 15th century, during Phase VI of the Templo Mayor’s construction and the reign of Axayacatl (1469 to 1481 CE). Six of these 38 tesserae came from Offering 125, at the foot of the Great Temple, near the Earth goddess Tlalocuhaltzin monolith (fig. S3) and which was deposited after Phase VI, during the reign of Ahuitzotl (1486 to 1502 CE) (table S1) (21). Although intact mosaics are present in some of these offerings, the tesserae analyzed were found at the bottom of these ritual deposits, already disarticulated with no wooden supports attached (fig. S4).

We also analyzed five tesserae associated with Mixteca-style turquoise mosaics currently held by the Smithsonian Institution in the collections of the National Museum of the American Indian (NMAI) (fig. S1). These mosaics were described in a 1922 monograph by Saville (16) and are believed to have been collected from a cave in the Mixteca region of the state of Puebla, Mexico (46). No other information on their provenience is known. The tesserae analyzed were not removed from the objects themselves, but were taken from a small jar of dirt, adhesives, and loose tiles associated with the mosaics (NMAI catalog # 10/8719). Samples from NMAI and Tenochtitlan’s Sacred Precinct range in size from about 1 cm (longest edge) to less than 5 mm (fig. S4).

**RESULTS AND DISCUSSION**

The Pb and Sr isotopic ratios of the tesserae are given in Table 1. Of the 43 tesserae analyzed, we were able to collect both Pb and Sr isotopic data on 31 samples. For the other 12 samples, we obtained either Pb or Sr isotopic ratios. When both Pb and Sr isotopic data are considered, 29 of the 31 tesserae fall outside the distribution of ratios for turquoise deposits in the Southwest (Fig. 2) (47). Furthermore, most of the objects form a tight cluster in isotope space, and the tesserae excavated from Tenochtitlan’s Sacred Precinct have similar ratios to those associated with the Mixteca-style mosaics from NMAI (Fig. 2). For these reasons, we suggest that most of the turquoise mosaic tiles analyzed for this study derive from the same or geologically similar source(s).

Although the tesserae have signatures that do not match those of any of the known turquoise deposits, their isotopic ratios provide constraints on their provenance. Notably, the $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of most tesserae are substantially lower than the $^{87}\text{Sr}/^{86}\text{Sr}$ ratios measured in Southwestern turquoise deposits (Figs. 2 and 3). For example, the lowest $^{87}\text{Sr}/^{86}\text{Sr}$ ratio measured on a sample of turquoise from the Southwest is 0.70624 (8). However, 30 of the 39 Mesoamerican samples for which we have data possess $^{87}\text{Sr}/^{86}\text{Sr}$ ratios that are lower (range, 0.70492 to 0.70622). One interpretation of these lower $^{87}\text{Sr}/^{86}\text{Sr}$ ratios is that these samples derive from deposits within Mesoamerica and possibly...
Table 1. Isotopic ratios of Aztec and Mixtec turquoise artifacts. N.D., not determined.

| Sample ID | Offering | $^{87}\text{Sr}/^{86}\text{Sr}$ | SE | $^{207}\text{Pb}/^{206}\text{Pb}$ | $^{208}\text{Pb}/^{206}\text{Pb}$ | $^{206}\text{Pb}/^{204}\text{Pb}$ | $^{207}\text{Pb}/^{204}\text{Pb}$ | $^{208}\text{Pb}/^{204}\text{Pb}$ |
|-----------|----------|----------------|----|----------------|----------------|----------------|----------------|----------------|
| Aztec mosaic tiles from the Sacred Precinct of Tenochtitlan |
| TM-1      | 125      | 0.70580        | 0.0016 | 2.0581      | 0.83373        | 18.800         | 15.675         | 38.694         |
| TM-2      | 125      | 0.70576        | 0.0008 | 2.0622      | 0.83560        | 18.721         | 15.643         | 38.605         |
| TM-3      | 125      | 0.70554        | 0.0008 | 2.0578      | 0.83153        | 18.813         | 15.643         | 38.734         |
| TM-8      | 125      | 0.70565        | 0.0013 | 2.0617      | 0.83537        | 18.817         | 15.636         | 38.589         |
| TM-9      | 125      | 0.70627        | 0.0013 | 2.0511      | 0.83155        | 18.840         | 15.672         | 38.645         |
| TM-19     | 125      | 0.70515        | 0.0013 | 2.0587      | 0.83153        | 18.813         | 15.643         | 38.734         |
| TM-5      | 1        | 0.70618        | 0.0010 | 2.0556      | 0.83257        | 18.801         | 15.652         | 38.645         |
| TM-10     | 1        | 0.70861        | 0.0009 | 2.0474      | 0.82817        | 18.924         | 15.672         | 38.745         |
| TM-11     | 1        | 0.70579        | 0.0007 | 2.0618      | 0.83543        | 18.723         | 15.642         | 38.603         |
| TM-32     | 1        | 0.70598        | 0.0010 | 2.0618      | 0.83546        | 18.721         | 15.641         | 38.600         |
| TM-12     | 11       | 0.70561        | 0.0015 | 1.9136      | 0.77403        | 20.303         | 15.716         | 38.854         |
| TM-33     | 11       | N.D.           | N.D.  | 2.0548      | 0.83342        | 18.797         | 15.665         | 38.622         |
| TM-21     | 11       | 0.70492        | 0.0015 | N.D.        | N.D.           | N.D.           | N.D.           | N.D.           |
| TM-13     | 13       | 0.70513        | 0.0010 | 2.0552      | 0.82892        | 18.889         | 15.655         | 38.814         |
| TM-22     | 13       | 0.70557        | 0.0033 | N.D.        | N.D.           | N.D.           | N.D.           | N.D.           |
| TM-23     | 13       | N.D.           | N.D.  | 2.0389      | 0.82542        | 18.967         | 15.656         | 38.672         |
| TM-30     | 13       | 0.70545        | 0.0007 | 2.0611      | 0.83536        | 18.728         | 15.645         | 38.600         |
| TM-14     | 17       | 0.70532        | 0.0008 | 2.0391      | 0.81894        | 19.154         | 15.686         | 39.056         |
| TM-15     | 17       | 0.70547        | 0.0010 | 2.0633      | 0.83534        | 18.734         | 15.649         | 38.654         |
| TM-24     | 17       | 0.70958        | 0.0053 | N.D.        | N.D.           | N.D.           | N.D.           | N.D.           |
| TM-36     | 17       | 0.70560        | 0.0010 | 2.0618      | 0.83431        | 18.764         | 15.655         | 38.687         |
| TM-7      | 20       | 0.70579        | 0.0008 | 2.0390      | 0.82169        | 19.081         | 15.680         | 38.906         |
| TM-25     | 20       | 0.70655        | 0.0007 | 2.0407      | 0.82427        | 18.993         | 15.658         | 38.763         |
| TM-26     | 20       | 0.70564        | 0.0010 | N.D.        | N.D.           | N.D.           | N.D.           | N.D.           |
| TM-34     | 20       | 0.70520        | 0.0010 | 2.0602      | 0.83383        | 18.771         | 15.652         | 38.673         |
| TM-35     | 20       | 0.70554        | 0.0010 | N.D.        | N.D.           | N.D.           | N.D.           | N.D.           |
| TM-16     | 60       | 0.70507        | 0.0010 | 2.0611      | 0.83550        | 18.719         | 15.641         | 38.583         |
| TM-17     | 60       | 0.70529        | 0.0010 | 2.0628      | 0.83601        | 18.710         | 15.641         | 38.595         |
| TM-28     | 60       | 0.70559        | 0.0008 | N.D.        | N.D.           | N.D.           | N.D.           | N.D.           |
| TM-37     | 60       | 0.71480        | 0.0007 | 1.9780      | 0.80346        | 19.536         | 15.713         | 38.683         |
| TM-38     | 60       | N.D.           | N.D.  | 2.037       | 0.82120        | 19.096         | 15.681         | 38.888         |
| TM-6      | 60       | 0.70607        | 0.0008 | 1.6922      | 0.69209        | 22.866         | 15.825         | 38.689         |
| TM-27     | 60       | 0.70538        | 0.0008 | 2.0400      | 0.82427        | 18.993         | 15.658         | 38.763         |

continued on next page
within western Mexico. In Mexico, the felsic rocks of the Sierra Madre Occidental, Sierra Madre del Sur, and Trans-Mexican Volcanic Belt host a number of copper deposits (48). In particular, copper porphyry mineralization extends southward from Arizona along the length of western Mexico to the state of Guerrero (39). Prior studies of felsic igneous rocks associated with these porphyry copper deposits have demonstrated that their initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios decrease along a north-south trend (39, 41). These different initial ratios account, in part, for regional variations in their present-day $^{87}\text{Sr}/^{86}\text{Sr}$ ratios. For example, in southeastern Arizona, most felsic rocks associated with copper porphyry deposits have modern $^{87}\text{Sr}/^{86}\text{Sr}$ ratios greater than $-0.708$ (49), while similar rocks in western Mexico (for example, Sinaloa, Jalisco, Michoacán, or Guerrero) frequently have values as low as $0.704$ or $0.705$ (39, 40, 50, 51). Because there are regional differences in the Sr isotope geochemistry of felsic magmatic rocks that host copper deposits, we would also expect there to be comparable differences in the Sr isotopic composition of any associated turquoise mineralization. Thus, we suggest that the lower $^{87}\text{Sr}/^{86}\text{Sr}$ ratios measured on most tesserae (compared to Southwestern turquoise deposits) indicate they derive from Mesoamerican and not Southwestern sources.

$^{207}\text{Pb}/^{206}\text{Pb}$ ratios provide a second, independent line of evidence that these objects may derive from a source or sources within Mesoamerica. Although the Pb isotopic signatures of the tesserae overlap with Southwestern turquoise deposits (fig. S5A), they cluster in a region of Pb isotopic space where they are collectively a poor match for any single deposit or group of deposits (fig. S5B). Notably, there is no overlap between the Pb isotopic composition of the tesserae and the turquoise.

| Sample ID | Offering | $^{87}\text{Sr}/^{86}\text{Sr}$ | % SE | $^{207}\text{Pb}/^{206}\text{Pb}$ | $^{208}\text{Pb}/^{206}\text{Pb}$ | $^{206}\text{Pb}/^{204}\text{Pb}$ | $^{207}\text{Pb}/^{204}\text{Pb}$ | $^{208}\text{Pb}/^{204}\text{Pb}$ |
|-----------|---------|-----------------|------|-----------------|-----------------|-----------------|-----------------|-----------------|
| TM-29     | 98      | 0.70529         | 0.0008 | 2.0588         | 0.83423         | 18.740          | 15.633          | 38.582          |
| TM-18     | 98      | 0.70622         | 0.0021 | 1.9868         | 0.80007         | 19.626          | 15.702          | 38.993          |
| TM-41     | 98      | 0.70574         | 0.0029 | N.D.           | N.D.            | N.D.            | N.D.            | N.D.            |
| Mixtec mosaic tiles from the NMAI (NMAI catalog # 10/8719) |
| NMAI-1    | 0.70637 | 0.0010          | 2.0289 | 0.81575        | 19.236          | 15.691          | 39.026          |
| NMAI-2    | 0.70659 | 0.0009          | 2.0370 | 0.82416        | 19.034          | 15.688          | 38.773          |
| NMAI-3    | N.D.    | N.D.            | 1.8448 | N.D.           | N.D.            | N.D.            | N.D.            |
| NMAI-4    | 0.70730 | 0.0010          | 2.0370 | 0.81831        | 19.182          | 15.697          | 39.073          |
| NMAI-5    | 0.70737 | 0.0013          | N.D.  | N.D.           | N.D.            | N.D.            | N.D.            |

Fig. 2. Pb versus Sr isotope plot comparing Aztec and Mixtec tesserae to geologic samples of turquoise from the Southwest. Note that Aztec and Mixtec tesserae form a relatively tight cluster in isotope space that falls outside the distribution of isotopic ratios measured on Southwestern turquoise. Data on Southwestern turquoise deposits are from Thibodeau et al. (8), and some data points on geologic samples lie beyond the range of the graph. Symbols are larger than errors.

Fig. 3. Box and whisker plot comparing $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of Aztec and Mixtec tesserae to geologic samples of turquoise from the Southwest. Data on Aztec and Mixtec tesserae are from this study (n = 39), and data on Southwestern turquoise deposits are from Thibodeau et al. (8) (n = 108). The tesserae have a median value of $^{87}\text{Sr}/^{86}\text{Sr} = 0.70574$ and an interquartile range of 0.70545 to 0.70621. Note that all the values within the tesserae’s interquartile range are lower than the lowest $^{87}\text{Sr}/^{86}\text{Sr}$ ratio yet measured on a turquoise sample from the Southwest. The three samples with the highest $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (TM-10, TM-24, and TM-37) derive from Offerings 1, 17, and 60, respectively, within the Templo Mayor, all of which date to the reign of Axayacatl (1469 to 1481 CE).
polities operated within and beyond their political boundaries (19). Thus, if turquoise was available from mines in the Tarascan region, then it is plausible the material entered the Aztec realm along with other commodities.

It is also possible that the Aztecs and Mixtecs acquired turquoise from other parts of western or central Mexico. The Codex Mendoza indicates that the Aztec received turquoise tribute from three provinces (Fig. 1) (22). The two southern (Mixteca) tributary provinces were Quiauhtlopán, which was located in what is today eastern Guerrero and possibly adjoining parts of Puebla, and Yoaltepec, which was located in present-day western Oaxaca. The northeastern province Tochpan was located in what is today northern Veracruz (Fig. 1). The Pb isotopic compositions of the tesserae partially overlap with the signatures of copper deposits in Veracruz [for example, compare to the study of Hosler and Macfarlane (43)], and may also overlap with the signatures of copper mineralization in Guerrero or Jalisco [see Hosler (53) and references therein] and with deposits in central Mexico [for example, compare to Potra and Macfarlane (44)]. Thus, the isotopic evidence also allows for the possibility that the inhabitants of these tributary provinces (including the Mixtecs) acquired turquoise from local sources or imported it from other parts western or central Mexico.

Unless direct evidence of ancient Mesoamerican turquoise mines comes to light, the specific source(s) of turquoise used by the Aztecs and Mixtecs cannot be identified. This is because neither the Pb nor Sr isotopic data are able to pinpoint the precise origin for these artifacts within Mesoamerica. However, the isotopic data provide strong evidence that none of the Aztecs or Mixtec turquoise artifacts analyzed for this study derive from the Southwest. Our data primarily pertain to turquoise objects associated with the Late Postclassic Aztec Empire and do not provide evidence about the source(s) of Mesoamerican turquoise artifacts from other regions or time periods. However, based on these findings, we suggest that turquoise may not have been an important component of long-distance trade between the Southwest and Mesoamerica.

**METHODS AND MATERIALS**

To ensure that all tesserae were turquoise (and not other blue-green minerals), we used nondestructive x-ray diffraction and scanning electron microscopy to examine their mineralogical and elemental compositions. Turquoise tesserae were prepared and analyzed for Pb and Sr isotopic ratios in the Department of Geosciences at the University of Arizona according to methods published elsewhere (8), but repeated here.

To remove any superficial contaminants or residue of adhesive material, the edges and faces of all tesserae were carefully sanded with a silicon carbide sandpaper and then inspected under a binocular microscope. After sanding, all samples were ultrasonicated in Milli-Q water (18.2 megohm), rinsed four to five times, and set to dry. Once dry, they were crushed with an alumina mortar and pestle. Between each sample, the mortar and pestle set was cleaned by grinding a slurry of silica sand and 200 proof ethanol and rinsing several times with ethanol and Milli-Q water.

All sample preparation procedures were conducted using ultrapure twice-distilled acids. After crushing, samples were weighed into acid-cleaned Savillex vials. Samples were then capped and refluxed in concentrated hydrochloric acid on a hotplate overnight at ~125°C. The next day, solutions were cooled and then, if necessary, centrifuged to remove any undigested material. The supernatant was dried down and redissolved in
8 M nitric acid. Pb and Sr were separated using Sr Spec resin (Eichrom Industries).

Strontium samples were loaded onto degassed tantalum filaments with phosphoric acid and tantalum gel to enhance ionization. Strontium isotope ratios were measured on a VG Sector 54 thermal ionization mass spectrometer in dynamic collection mode at the University of Arizona. Fractionation was corrected using a $^{88}\text{Sr}/^{86}\text{Sr}$ ratio of 0.1194. The National Institute of Standards and Technology (NIST)-987 standard was run before, during, and after samples during each analytical session. The average value of the NIST-987 standard over all analytical sessions was 0.710266 ± 0.000014 (2 SD, n = 19).

Lead isotope measurements were made on a GV-Isotrace multi-collector inductively coupled plasma mass spectrometer. To correct for fractionation, samples were spiked with TI to achieve a Pb/TI ratio of approximately 10. Samples were Hg-corrected and empirically normalized to TI after methods used by (55). All samples were then normalized to the values of Galer and Abouchami (56) for the NIST-981 standard. The NIST-981 standard was run before, between, and after the samples, and sample and standard concentrations were matched within 20%. The errors on the Pb isotope ratios were calculated from the reproducibility of the NIST-981 standard over the course of each measurement session. Errors associated with each sample are given in Table S2.

**SUPPLEMENTARY MATERIALS**

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/4/6/eaas9370/DC1

fig. S1. Mixtec-style shield decorated with turquoise mosaic from the collections of the Smithsonian Institution—NMAI.

fig. S2. Reconstructed turquoise mosaic disk from Offering 99 in the Templo Mayor.

fig. S3. Location of offerings with turquoise in the Sacred Precinct of Tenochtitlan.

fig. S4. Examples of analyzed mosaic tiles from Offering 60 in the Templo Mayor.

fig. S5. Pb isotope plots comparing Aztec and Mixtec tesserae to turquoise deposits from the Southwest.

fig. S6. Pb and Sr isotope plots comparing Aztec and Mixtec tesserae to turquoise deposits of the Cerillos Hills, New Mexico.

Table S1. Offerings with turquoise within the Sacred Precinct of Tenochtitlan.

Table S2. Errors on Pb isotope ratios.

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Acknowledgments: We thank P. Meehan at Mexico’s Instituto Nacional de Antropología e Historia for assistance with the selection of samples from Tenochtitlan. We also thank G. Chiari of the Getty Conservation Institute for conducting nondestructive x-ray diffraction on some of the analyzed artifacts from Tenochtitlan. We are indebted to P. Niefeld, Supervisory Collections Manager at the Cultural Resources Center of the NMAI for facilitating our access to and understanding of their Mixtec turquoise artifacts and materials. S. Scott initiated our investigations into the NMAI turquoise objects, and we wish to express our special appreciation and recognition for her diligent and insightful research. We are very grateful to M. Baker at the University of Arizona for assistance with the isotopic analyses. We also thank J. Ciarrocca at Dickinson College for assistance with the making of Fig. 1. The initial stages of this research were supported by the Florence C. and Robert H. Lister fellowship to A.M.T. Author contributions: All authors jointly conceived of and designed the research. L.L.L. and his team excavated and recorded the turquoise artifacts from Tenochtitlan and selected the Aztec samples for this project. F.F.B. and A.M.T. selected the Mixtec samples from NMAI and obtained permission for their analysis. A.M.T. prepared the samples, measured the isotope ratios, and processed the data in the laboratory of J.R. A.M.T. interpreted the data and wrote the manuscript with significant contributions from all the other authors. Competing interests: The authors declare that they have no competing interests. Data and materials availability: All data needed to evaluate the conclusions in the paper are present in the paper and/or the Supplementary Materials. Additional data are available from the authors upon request.

Submitted 7 January 2018
Accepted 3 May 2018
Published 13 June 2018

Citation: A. M. Thibodeau, L. López Luján, D. J. Kilkick, F. F. Berdan, J. Ruiz, Was Aztec and Mixtec turquoise mined in the American Southwest? Sci. Adv. 4, eaas9370 (2018).

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Author contributions: All authors jointly conceived of and designed the research. L.L.L. and his team excavated and recorded the turquoise artifacts from Tenochtitlan and selected the Aztec samples for this project. F.F.B. and A.M.T. selected the Mixtec samples from NMAI and obtained permission for their analysis. A.M.T. prepared the samples, measured the isotope ratios, and processed the data in the laboratory of J.R. A.M.T. interpreted the data with input from all the other authors. A.M.T. and D.J.K. wrote the manuscript with significant contributions from all the other authors.

Competing interests: The authors declare that they have no competing interests.

Data and materials availability: All data needed to evaluate the conclusions in the paper are present in the paper and/or the Supplementary Materials. Additional data are available from the authors upon request.

Submitted 7 January 2018
Accepted 3 May 2018
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10.1126/sciadv.aas9370

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Sci Adv 4 (6), eaas9370.
DOI: 10.1126/sciadv.aas9370

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