normal pressure to the west of the American topography should impart a "mountain" torque that would decelerate the solid earth while accelerating the atmosphere. This hypothesis, at least, is consistent with the sign of the anomalies we have detected in the momenta of the solid earth and the atmosphere around January 1983. Actual calculations are needed to verify whether the amplitude of this mountain torque is sufficient to account for the size of the anomalies.

The equatorial Pacific warming episode of 1982–1983 had widespread biological, economical, and physical impacts (*9*, *22*). Its effect on the atmosphere appears to have been especially profound and will be the subject of much further research. The results reported here suggest that, through its link with the atmosphere, this oceanic event even had a detectable influence on the motion of the solid earth.

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Analysis of Obsidian from Moho Cay, Belize: New Evidence on Classic Maya Trade Routes

Abstract. *Trace element analysis of obsidian artifacts from Moho Cay, Belize, reveals that the obsidian derives primarily from the El Chayal outcrop in highland Guatemala and not from the Ixtepeque source. This is contrary to the widely accepted obsidian trade route model for Classic Maya civilization and suggests that Classic Maya obsidian trade was a more complex economic phenomenon than has been recognized.*

More than a decade ago Hammond proposed a trade model to explain the distribution of obsidian artifacts at Classic Maya centers in the lowlands (*1*). Trace element analysis by x-ray fluorescence (XRF) and neutron activation (NAA) revealed a heavy reliance on two primary sources of obsidian—at El Chayal and Ixtepeque—during the Classic Period (A.D. 250 to 900). Both are located in the volcanic highlands of Guatemala, which is a considerable distance from the lowland Maya centers of obsidian use in Guatemala, Belize, and Mexico (Fig. 1). From analyses of obsidians from 23 lowland Maya sites, Hammond proposed that the movement of the valued volcanic stone most likely followed trade routes along major river valleys: (i) from El Chayal to the Maya interior lowlands by the Usamacinta and Sarstoon basins and (ii) from Ixtepeque, down the Motagua River to the Caribbean, and thence up the Belize-Mexico Yucatán coast.

The distribution of obsidian from the two sources appeared to be largely complementary, overlapping at or near Tikal in the central Maya lowlands. This suggested to Hammond that the two highland sources were being exploited contemporaneously during the Classic Period and that there was a level of competition between them for the lowland Maya market.

The validity of the two-pronged trade route has been questioned as the sources of more samples of obsidian have been identified. Some samples from the western lowland site of Seibal, for example, proved to have been derived from El Chayal, as predicted by the trade model, but others were from Ixtepeque and two other sources (*2*). Johnson raised additional queries after determining the sources of samples from Palenque and surrounding sites (*3*). As was the case at Seibal, most of the obsidian was derived from El Chayal, but there were specimens from Ixtepeque, San Martin Jilotepeque, Pachuca, and possibly Zaragosa. The distribution of obsidian in the western Maya lowlands did not convincingly support the trade model.

Some sources of Guatemalan obsidian appear to have been used more heavily at different times (*4*), indicating that obsidian from Classic Period deposits should be selected to analyze Classic Period obsidian trade routes. Hammond refined his model with data on obsidian from several sites located in southern Belize (*5*). The Classic Maya center of Lubaantun, for example, located but 25 km from the coast on several waterways, had no Ixtepeque obsidian at all (*6*). Islands off the southern coast of Belize received Ixtepeque obsidian, as predicted by the original model, but also El Chayal obsidian.

In reexamining the trade model, Hammond (*5*) suggested that during the Classic Period there were several transshipment points on a coastal Yucatán trade route between such major ports as Cozumel and Nito: there were "way stations where large trading canoes would put in

Table 1. Results of x-ray fluorescence analysis of obsidian samples from Middle Classic Period (A.D. 400 to 700) deposits at Moho Cay, Belize.

Catalog number	Unit	Depth	Context	Ba (ppm)	Fe (%)	Zr (ppm)	Sr/Zr	Rb/Zr	Source
37/193-1-53	1	40–50 cm	Domestic refuse	1044	0.86	168	0.887	0.547	Ixtepeque
37/193-1-106	2a	50–70 cm	Feature 4 burial	799	0.63	115	1.365	1.359	El Chayal*
37/193-1-158	2a	50–70 cm	Feature 4 burial	810	0.63	108	1.395	1.440	El Chayal
37/193-1-158	2a	50–70 cm	Feature 4 burial	877	0.66	113	1.376	1.395	El Chayal
37/193-1-13	4	10–20 cm	Domestic refuse	881	0.63	114	1.394	1.391	El Chayal
37/193-1-19	4	20–30 cm	Domestic refuse	925	0.59	116	1.319	1.355	El Chayal
37/193-1-42	5, 5a and 5b	20–30 cm	Feature 1 burial	889	0.57	118	1.298	1.294	El Chayal
37/193-1-20	6	10–20 cm	Feature 7 manatee midden	899	0.57	111	1.345	1.346	El Chayal
37/193-1-170	6 and 6a	21.5 cm	Feature 7 manatee midden	916	0.63	117	1.341	1.334	El Chayal
37/193-1-104	8a	27–34 cm	Feature 5 burial fill	914	0.59	115	1.333	1.311	El Chayal
37/193-1-104	8a	27–34 cm	Feature 5 burial fill	889	0.62	116	1.345	1.335	El Chayal
37/193-1-113	18	40–50 cm	Domestic refuse	916	0.68	119	1.410	1.407	El Chayal*
37/193-1-113	18	40–50 cm	Domestic refuse	922	0.59	114	1.354	1.315	El Chayal
			El Chayal reference	915	0.627	117	1.31	1.27	
			Ixtepeque reference	1030	0.923	176	0.90	0.57	

*Samples that were checked further by NAA (Table 2).

to off-load and take on goods from the mainland; such stations would habitually be on small islands off the coast, and from their small size and unsuitability for settlement on any substantial scale might well have functioned as *de facto* ports-of-trade. . . ." One site specifically designated as a "way station" was Moho Cay, near Belize City. Excavations at this site, however, raise some concerns about the utility of the current Maya obsidian trade model (*7*).

Moho Cay, a small flat island near the mouth of the Belize River (Fig. 1), measured 250 by 320 m in 1980. Only a small area of the northern point was dry and grass-covered in 1979; the rest of the island lay in mangrove. Archeological remains are known to have been eroding from the site since the 19th century and have been recovered from underwater survey around the site (*8, 9*). Gann reported on large quantities of manatee bone on the cay (*10*). For years the island had been looted and was generally identified as a prehistoric fishing station (*11*). Although there were no mounds or other structures, abundant sherds, chert, and obsidian were found on the northern point of the cay in 1978 and 1979 (*9, 12*). The island site was effectively destroyed in 1980 by a dredging operation to create a commercial marina (*13*).

Data from excavated remains as well as substantial surface collections indicate that the principal Maya use of the cay was during the Middle Classic (A.D. 400 to 700) (*9, 14*). Late Preclassic and Late Postclassic material from the surface collections point to use of the island at these times as well.

That Moho Cay served as a trade "node" for prehistoric Maya traders, as suggested by Hammond, seems likely.

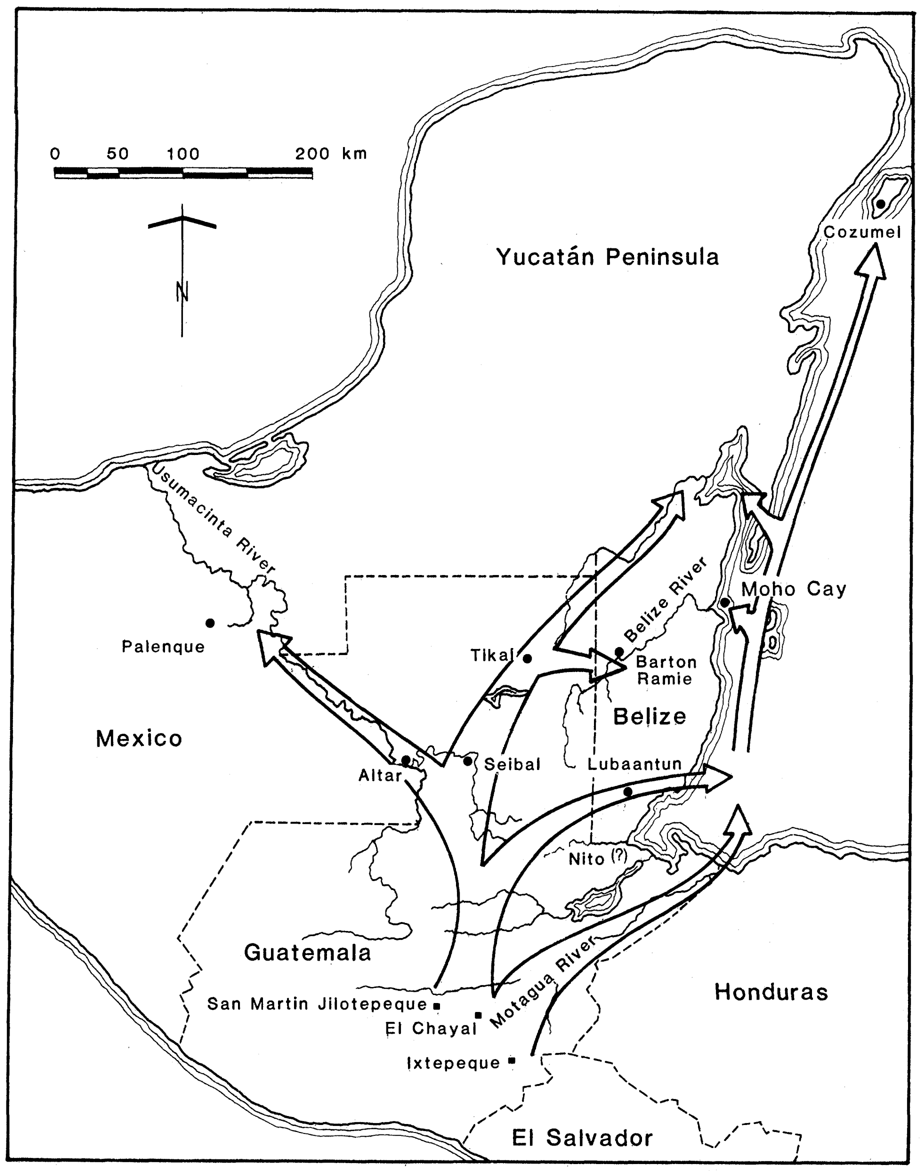

Fig. 1. Map of the Maya subarea indicating the location of Moho Cay (Belize) and possible obsidian trade routes. Major obsidian sources in the Guatemalan highlands are Ixtepeque, El Chayal, and San Martin Jilotepeque [after Hammond (*22*)].

Table 2. Results of an abbreviated neutron activation analysis of obsidian samples from deposits at Moho Cay, Belize.

Catalog number	Dy (ppm)	Mn (ppm)	Na (%)	K (%)	Ba (ppm)	Source
37/193-1-53	2.73 ± 0.11	656 ± 13	3.28 ± 0.07	3.44 ± 0.18	912 ± 44	El Chayal
37/193-1-113	2.66 ± 0.12	660 ± 13	3.26 ± 0.07	3.74 ± 0.18	973 ± 43	El Chayal
El Chayal reference	2.66 ± 0.11	649 ± 13	3.15 ± 0.06	3.46 ± 0.25	915 ± 35	
Ixtepeque reference	2.30 ± 0.11	449 ± 9	3.05 ± 0.05	3.61 ± 0.26	1030 ± 27	

First, the cay is ideally suited for such a function: near the mouth of the Belize River, one of the most important rivers flowing from the interior of the central Maya lowlands. Furthermore, the cay is also at the juncture of this river and the proposed coastal canoe route along the Yucatán Peninsula, making it perfectly situated to facilitate shipment of trade goods destined for the interior from coastal ports to the north or south and vice versa.

Second, the nonlocal origin of a large proportion of the artifacts from Moho Cay also indicates that the island community had an important role in Classic Maya trade. The large quantity of polychrome ceramics was undoubtedly imported; utilitarian ceramics for domestic use were also found (*9*). The highly distinctive Teotihuacán-style slab-footed cylinder vessels are probably exotic imports (*15*). Although no chert outcrops occur on the cay, chert implements were unusually abundant (*9, 16*). The numerous complete artifacts and small quantity of chert waste material indicate that the artifacts were manufactured on the mainland, with only some finishing and retouching at Moho Cay. A remarkable amount of chert tool manufacturing is documented for the northern Belize site of Colha (*17*), and some at other sites in northern Belize, an area with extensive outcrops of quality chert (*18*).

Obsidian was also abundant, both from surface collections and excavations at Moho Cay. Since the source of obsidian can be traced, 13 obsidian samples, representing 10 percent of the excavated obsidian, were selected for analysis on the basis of secure provenience and dating. The samples, derived from ten different excavations dating to the Middle Classic Period (A.D. 400 to 700), were gray prismatic blades and were analyzed by nondestructive XRF and NAA (Table 1) (*19, 20*). The relative abundance of the trace elements Ba, Fe, Sr, Rb, and Zr is particularly useful as a comparative index for obsidian samples from well known geological sources in Mexico, Guatemala, El Salvador, and Honduras. In two cases, the XRF identifications were checked by a more complex, short neutron activation method that focused on the elements Dy, Mn, Na, K, and Ba (Table 2).

Twelve of the 13 samples were identified as originating at the El Chayal source of highland Guatemala, and one was from Ixtepeque.

The most commonly accepted model (*1*) for Classic Maya obsidian trade projects that ". . . Ixtepeque obsidian was taken down the Rio Motagua and north up the Caribbean coast and then brought inland, upriver or on overland routes." El Chayal obsidian is overwhelmingly dominant at Moho Cay, whereas the model proposes that Ixtepeque sourcing would predominate at such a coastal site.

Moho Cay trace element analysis suggests that prehistoric Maya obsidian trade mechanisms, trading dynamics, and commodity distribution were more intricate than the dual route, interior-coastal model. Demand for obsidian during the Classic Period was very high, and it is likely that there was no monopoly on the sources or their routings. The growing body of evidence suggests, instead, that both El Chayal and Ixtepeque, as well as other highland sources, were being exploited and that obsidian was being traded throughout the lowlands by multiple routes (*4, 19, 20*).

The high percentage of El Chayal obsidian in the Classic Period sample from Moho Cay supports the interpretation that El Chayal was a major obsidian source for coastal as well as interior Classic Maya lowland sites. El Chayal obsidian may have reached coastal communities by interior and coastal transportation routes. Certainly canoe transport along the Motagua and Caribbean would have been the most direct way for both El Chayal and Ixtepeque obsidian. The high proportion of El Chayal obsidian at Moho Cay, and indeed at other Classic Period coastal settlements in Belize, reinforces the interpretation that El Chayal obsidian may have been transported from Guatemala down the Motagua River and north along the Caribbean coast.

Some El Chayal obsidian may have been transported by way of the Guatemalan Alta Verapaz highland region to the southern coast of Belize by an interior route that may also have been used to transport cacao (*5, 21*). This El Chayal obsidian could then have been transported by canoe up the Yucatán coast to offshore islands such as Moho Cay. Alternatively, El Chayal obsidian transported by an interior route to Tikal in the Guatemalan Peten may have been carried overland to the Belize River for transport by canoe to the coast (*22*). Certainly, the source of the Classic Period obsidian that has been analyzed from Tikal has been largely El Chayal (*23*), as has the source of samples from Barton Ramie in the Belize Valley (*24*).

The predominance at Moho Cay of obsidian from the Guatemalan highland source of El Chayal during the Middle Classic is counter to the model for Classic Maya obsidian trade that projects that Maya sites along the east coast of Belize and Mexico would most likely have been served by Ixtepeque. It appears, instead, that Classic Maya obsidian procurement and distribution were more complex and that the patterns of trade in the Classic Period can only be adequately assessed by reference to temporally specific samples with a more in depth consideration of the socioeconomic nature of this trade (*4*).

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New Findings on the Congenital Transmission of Avian Leukosis Viruses

Abstract. *RAV-0, an endogenous avian leukosis virus, does not undergo congenital transmission in infected K28 chickens. In contrast, avian leukosis viruses of exogenous origin undergo highly efficient congenital transmission. The relative abilities of endogenous and exogenous viruses to undergo congenital transmission appear to be determined by the p27 capsid proteins of these viruses.*

Field strains of avian leukosis viruses (ALV's) have long been known to undergo efficient congenital transmission (*1*). These viruses replicate through the reproductive tract of the hen, with the highest numbers of budding virus occurring in the magnum- or albumen-secreting region of the oviduct (*2*). Developing embryos become infected and hatch into chicks whose immune systems recognize the virus as self (*3*). A persistent viremia is established with each generation of viremic hens spawning viremic progeny.

To study the biology of endogenous viruses, we have developed a randomly bred line of K28 chickens that is susceptible to endogenous virus infections (*4*). Endogenous viruses replicate well in K28 chickens, establishing levels of viremia comparable to those observed in K28 chickens infected with exogenous ALV's (*5*). As expected, K28 hens infected with exogenous ALV's shed high titers of virus into egg albumen. However, K28 hens infected with the endogenous virus RAV-0 did not shed virus into egg albumen (Table 1).

To define which region of the genome of endogenous viruses restricted the shedding of virus into eggs, we examined eight recombinants of endogenous and exogenous ALV's for their ability to undergo congenital transmission (Table 2). Four of these (RAV-60's) were generated during growth of exogenous viruses in cells that expressed replication-defective endogenous viruses (*ev* 3 or *ev* 9) (*6*). Two (NTRE-2 and NTRE-7) were generated during mixed infection of cells with an exogenous virus and an endogenous virus (*7*). The remaining recombinants (recALV's) were recovered from DNA constructions that recombined specific fragments of molecularly cloned proviral DNA's.

Tests for the congenital transmission of the recombinant viruses were performed on viremic K28 layers. Only layers with 10^5 or more infectious units of virus per milliliter of serum were examined for shedding of virus into eggs (*8*). The presence of virus in egg albumen was assayed by incubating albumen with antiserum to the group-specific antigens of ALV's and then testing for complement fixation (*9*). Most albumens containing virus scored positive at the highest dilution tested (1:16). Five of the eight recombinant viruses underwent efficient egg transmission while three did not (Table 2).

The recombinants were grouped as to whether or not they were shed into egg albumen (Table 3). The genomes of the recombinants were then scored for markers from their endogenous and exogenous parents. Most markers were oligonucleotides that were diagnostic for the endogenous or the exogenous parents of the recombinants (*6, 7*). The host range of the recombinant was used as a marker for gp85 sequences, with N designating the subgroup E host range that is characteristic of endogenous ALV's (*10*). The electrophoretic mobility of the p27 protein was used as a marker for

Table 1. Congenital transmission of exogenous but not endogenous ALV's in K28 chickens. Albumens were collected from freshly layed eggs of K28 hens that had been intravenously inoculated at 1 day of age with approximately 1×10^6 infectious units of the indicated viruses. pRAV-1 is virus recovered from RAV-1 proviral DNA cloned into the Sac I site of pBR322. pRAV-0 is virus recovered from RAV-0 proviral DNA cloned into the Sal I site of pBR322. Sera were collected from laying hens, and virus was measured by assaying for the amount of particulate RNA-directed DNA polymerase. Under our assay conditions, 1 count/min is equivalent to approximately 100 infectious units of virus (*8*). ALV group-specific antigens were determined by assaying for complement fixation in reactions of egg albumen and antiserum to group-specific antigens (*9*). The group-specific antigens in egg albumen appeared to be in mature virus since they had the electrophoretic mobilities that are characteristic of the viral (p27, p19, p15, p12) rather than the precursor forms (Pr76, Pr66) of group-specific (gs) antigens (*14, 15*). N.T., not tested.

Virus	Subgroup of virus	Number of hens	Viremia (infectious units per milliliter)	gs^+ albumens/ albumens tested
			Exogenous	
RAV-1	A	2	N.T.	7/7
pRAV-1		1	2×10^7	4/4
tdPr-B	B	2	N.T.	4/4
			Endogenous	
RAV-0	E	27	N.T.	0/81
pRAV-0		5	1×10^6 to 5×10^6	0/15