of brine or solid salt, located adjacent to or under the sea afford a unique solution. The brine or salt dissolved from the domes could be pumped to the surface and interfaced with the seawater (or nearby groundwaters similarly pumped). Disposal of the end product would be no major problem, provided that it can be amply diluted in the sea and that it contains no petroleum remnants. If environmentally harmful substances are present, the final solution can be reinjected into the earth. Salt domes have been of interest because of their tendency to contain oil and gas deposits. Many salt domes have been monitored and drilled, particularly along the coastal zone of the Gulf of Mexico. These domes have been the source of some of the largest oil finds in the United States. Thus, it is surprising to consider that there may be greater amounts of energy available from the salt in the salt domes than is obtained from the oil and gas.

An extremely productive salt dome can yield 10^8 barrels of oil (1 barrel = 0.14 metric ton), but most domes yield less. Very few of the salt dome oil fields, such as Hastings West in Texas District 3 and Cailou Island in Louisiana South, are capable of producing as much as 6×10^8 barrels (*5*). If we consider that 1 barrel of oil is equivalent to 5×10^6 Btu's $\simeq 5 \times 10^9$ J = 170 W-years, a productive dome can yield 1.7×10^4 MW-years of energy. By comparison, the domestic demand in the United States for all petroleum products in late 1977 averaged 17.5×10^6 barrels per day (*6*), which would be about 10^6 MW-years for 1977.

A typical salt dome is about 1600 m in diameter and 1600 m in depth and has a volume of approximately 3.2×10^9 m^3 (0.75 cubic mile) of salt. The mass of salt in such a salt dome is about 7.1×10^{15} g if it is essentially pure NaCl, which is often the case. If other salts are present, they may be harmful to the membranes proposed for some of the conversion methods. Thus, they would have to be removed or other methods would be required. If the salt is dissolved in seawater until it has an osmotic pressure of 370 atm, 3.2×10^9 m^3 of salt would yield 2.8×10^4 MW-years of energy when diluted with seawater and recovered at 100 percent efficiency (*4*). Thus, even for a highly productive well, the salt is more energetic in theory than the oil. Table 1, which gives data for some actual examples (*7*), demonstrates even more clearly the partition of energy. We have listed the most productive wells, some average producers, and some below-average producers. There are many more oil wells in the below-average category than in the highly productive category.

Moreover, there are more "dry holes" than "strikes." Of the hundreds of salt domes that have been drilled, the majority contain no oil. Thus, the salt in salt domes is a large untapped source of energy even if it can only be converted at 5 percent efficiency. Research and development should improve our capability to capture this energy. Because of the present lack of information, it is not possible to estimate a likely efficiency but it could be higher than 25 percent.

Salinity gradient energy is a form of solar energy and is continuously renewed in the case of rivers flowing into the ocean or of inundated salt pans whose brine concentration is controlled by solar evaporation. The salt domes are examples of stored solar energy and are consequently nonrenewable on the short geological time scale. As is the case for oil and gas, once the salt in such domes is mined and utilized, it is gone for eons.

In addition to the salt domes, there are immense salt deposits in the Mississippi Valley and under the Great Plains, as well as in other places. If these deposits are near subterranean sources of brackish water, they also could be used to produce energy and the brine end product could be disposed of by reinjection into the earth.

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Peyote Alkaloids: Identification in a Prehistoric Specimen of *Lophophora* from Coahuila, Mexico

Abstract. *Mescaline, anhalonine, lophophorine, pellotine, and anhalonidine have been identified in alkaloid extracts of a prehistoric specimen of* Lophophora *from a burial cave in west central Coahuila, Mexico. The specimen is associated with radiocarbon dates of A.D. 810 to 1070 and is one of the oldest materials ever submitted to alkaloid analysis.*

In 1941, Taylor conducted a brief but thorough salvage excavation in a small site, designated as CM-79, in west central Coahuila, Mexico (*1*). The site, a multiple interment burial cave, produced a variety of lithic and perishable artifacts ascribable to the so-called Mayran mortuary complex, which is centered in the Laguna District of southwest Coahuila (*2*). Site CM-79 is essentially a single component locality and is reasonably well dated by a series of three radiocarbon dates of A.D. 810 ± 70, 1020 ± 60, and 1070 ± 75 (*3*). These assays were performed on samples of plaited matting directly associated with the burials at this site.

Among the Mayran mortuary materials recovered from CM-79 were a number of peyote (*Lophophora williamsii*, Cactaceae) buttons strung on a cord and superficially resembling a necklace. One of these buttons was removed from the "necklace" and subjected to alkaloid analysis. The results of that analysis (*4*) follow.

The specimen chosen for the analysis (1.425 g) was ground to a fine powder in a mortar, mixed with ethanol to a slurry, stirred for 48 hours, and filtered. The ethanol extract was evaporated to dryness. The residue was dissolved in water, made alkaline with concentrated ammonia (*p*H 9), and extracted twice with chloroform and once with a mixture of chloroform and ethanol (3 : 1). The combined chloroform extracts were evaporated to dryness to yield 32 mg (2.25 percent) of alkaloids. These were resolved into phenolic (35 percent) and nonphenolic (65 percent) portions, as previously described (*5*).

Analytical thin-layer chromatography (TLC) was carried out on coated 0.25-mm silica gel F_{254} aluminum sheets in mixtures of chloroform, ethanol, and

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Table 1. Mass spectral data for extracted peyote alkaloids and reference compounds.

Compound	*m/e* (relative intensity)				
	Nonphenolic alkaloids				
Peak 1	211 (M^+, 13%),	182 (61.5%),	181 (36%),	167 (29.5%),	30 (100%)
Mescaline	211 (M^+, 15%),	182 (61.5%),	181 (31%),	167 (31%),	30 (100%)
Peak 2	235 (M^+, 1.4%),	221 (19%),	220 (100%),	205 (17%)	
Lophophorine	235 (M^+, 1.6%),	221 (15%),	220 (100%),	205 (7%)	
Peak 3	221 (M^+, 4%),	207 (17%),	206 (100%),	191 (17%)	
Anhalonine	221 (M^+, 6%),	207 (15%),	206 (100%),	191 (8%)	
	Phenolic alkaloids				
Peak 1	237 (M^+, 1.1%),	223 (20%),	222 (100%),	207 (12%),	161 (44%)
Pellotine	237 (M^+, 0.7%),	223 (20%),	222 (100%),	207 (13%),	161 (40%)
Peak 2	223 (M^+, 2.6%),	209 (18%),	208 (100%),	147 (41%)	
Anhalonidine	223 (M^+, 3%),	209 (16%),	208 (100%),	147 (47%)	

concentrated ammonia (85:15:0.4) and chloroform, ethanol, and diethylamine (85:10:5). The nonphenolic alkaloids showed two components giving R_F values and color reactions (*6*) similar to those of mescaline (3,4,5-trimethoxyphenethylamine) and anhalonine (1-methyl-6-methoxy-7,8-methylenedioxy-1,2,3,4-tetrahydroisoquinoline). In the same way, TLC of the phenolic extract pointed to the presence of anhalonidine (1-methyl-6,7-dimethoxy-8-hydroxy-1,2,3,4-tetrahydroisoquinoline) and pellotine (1,2-dimethyl-6,7-dimethoxy-8-hydroxy-1,2,3,4-tetrahydroisoquinoline)as the major components. Both extracts also exhibited unidentified spots with high R_F values.

Gas chromatography (GC) (*7–9*) was used to further verify the presence of the above-mentioned alkaloids. The nonphenolic alkaloids (Fig. 1) gave several peaks on GC, three of which corresponded in their retention times to mescaline, anhalonine, and lophophorine (1,2-dimethyl-6-methoxy-7,8-methylenedioxy-1,2,3,4-tetrahydroisoquinoline), respectively. The phenolic alkaloids gave two major peaks on GC (Fig. 2) and these had the same retention times as authentic pellotine and anhalonidine.

For the final identification of these five alkaloids, we used gas chromatography–mass spectrometry (GC-MS) (*10*). The appropriate peaks in the two alkaloid extracts gave mass-to-charge (*m/e*) ratios and fragmentations consistent with the TLC and GC findings (Table 1).

All the alkaloids now identified are present in dried tops of *Lophophora williamsii*, "mescal buttons" (*11*). Recently prepared mescal buttons contain about a total of 8 percent alkaloids, 64 percent of which are phenolic (*12*). An 85-year-old sample of "mescal buttons" showed only minor differences in alkaloid composition, but the now-investigated thousand-year-old specimen has a considerably lower alkaloid content (2.25 percent) and only 35 percent are phenolic alkaloids. Some unidentified spots (TLC) and peaks (GC) are probably due to alkaloid degradation products, since they cannot be seen in extracts of new "mescal buttons."

Several studies have indicated the persistence of alkaloids in plant tissues (*13*), but only a few samples have been as old as the one now investigated. *Ilex guayusa* leaves, found in a medicine man's tomb in Bolivia and ^{14}C-dated to A.D. 375, were analyzed for alkaloids and found to still contain caffeine. Traces of nicotine were identified in a tobacco sample from the same tomb (*14*).

The finding of mescaline and related tetrahydroisoquinoline alkaloids in the thousand-year-old drug not only shows the remarkable stability of these compounds in dry, nonpowdered plant tissue but also supports the botanical identification as *Lophophora williamsii*.

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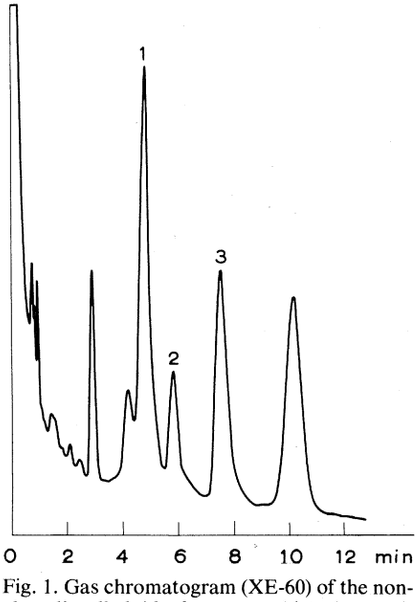

Fig. 1. Gas chromatogram (XE-60) of the nonphenolic alkaloids from a prehistoric specimen of *Lophophora*.

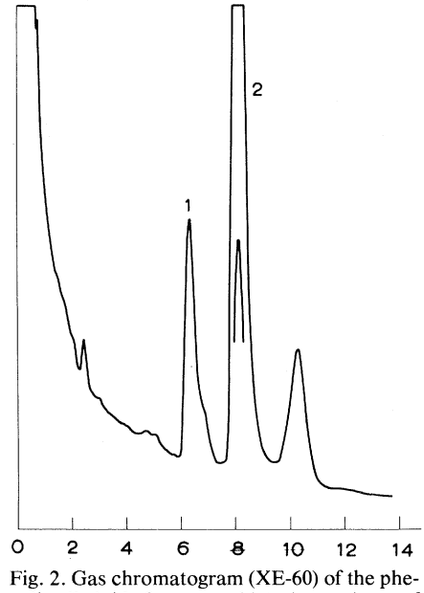

Fig. 2. Gas chromatogram (XE-60) of the phenolic alkaloids from a prehistoric specimen of *Lophophora*.

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