AN OVERVIEW OF THE HISTORICAL ASPECTS OF GEOTHERMAL ENERGY IN MESOAMERICA

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ABSTRACT

Mesoamerica is a zone with ubiquitous geothermal manifestations that have always influenced the lives of its inhabitants through the increased fertility of volcanic soils and the damage inflicted on lands, settlements and crops by volcanic eruptions or earthquakes. Some materials of igneous origin. like obsidian and jade, were of utmost importance for the region's people. However, the influence of geothermal phenomena went beyond their material implications, to affect even religious matters.

The Europeans coming over to this zone reacted tu its geothermal manifestations with awe, which was soon followed by attempts to explain their characteristics through the scientific theories current at the time, or to exploit them. The present paper seeks to summarize the interactions, both, in utilitarian and in nonmaterial planes, between man and geothermal energy in Mesoamerica.

1. INTRODUCTION

Industrial exploitation of geothermal resources did not start in Mesoamerica until the second half of the 20th Century. So. to comply with the limitations of this Historical Session. we will refer to geothermal energy in its widest sense. mentioning the utilization its inhabitants made of earth's heat or igneous materials, and also the way in which phenomena, like earthquakes or volcanic eruptions, influenced the lives of those peoples. their societies and their beliefs.

To establish the early history of the geothermal influences in Mexico, Central America and the Antilles is a very difficult task for various reasons, mainly that our sources are fragmentary and often distorted. Besides, not until the studies of Knoronosov, in 1952, and Proskouriakoff, in 1960, were the Mayan inscriptions properly deciphered. Before that. we only had second-hand transcriptions made by the Colony missionaries, who considered the beliefs of tlie aboriginal populations the work of demons. On the other hand, although the primitive inhabitants of Mesoamerica left proof of their perception of geothermal phenomena in the toponymy and in their thwgony, they were not much interested in utilitarian aspects, so they left very few records of the world that surrounded them.

2. THE PEOPLING OF MESOAMERICA

In 1589, the Spanish Jesuit Jose de Acosta advanced the idea that American Indians had first come froiii Asia by land and, perhaps, a short sea voyage. This is still the opinion commonly held, with the majority of experts dating the first human occupation tu *circa* 11,000 B.P. and some of them fixing it as far back as 25,000 B.P.

In any event, America was first colonized by modern humans that had already acquired many skills and had presumably developed some system of beliefs. Evidence from archeological findings, anthropological measurements, analyses of mitochondrial DNA and studies of comparative linguistics all concur that Mesoamerica was originally settled by the *Amerind* peoples on their migration from Asia. After an archaic epoch in which the land was settled for the first time, the interval of human occupation is divided in three periods: the earliest one, termed "*Preclassic*" *(or "Formative")* lasts from about 4,000 B.P. lo 1,800 B.P.. The next period, the *Classic*, extends to about 1,100 B.P.. while the *Postclassic* ends with tlie Spanish Conquest.

3. THE REGION

Mesoamerica is a land of very intense tectonic activity, so its first colonizers should have become acquainted with seismic, volcanic and geothermal manifestations very soon. Chronologically, their first contact with these phenomena should have happened in the *Imperial* and the *Mexicali* valleys, where they could not have overlooked the conspicuous hot springs, mud volcanos. steam jets, mineral inflorescences, etc. Similar manifestations should have also been evident to those arriving to the *Neovolcanic Belt*, with its 3000 volcanic cones, abundant hydrothermal deposits and numerous hot springs (Cataldi *et al.*, 1993). In Central America, the situation is comparable: Guatemala with peaks such as *Santa María* and *Fuego* and lakes formed in volcanic craters. like *Atitlán* and *Amatitlán*; Honduras, with *Conchagua* among others: El Salvador, with its central valley so affected by seismic activity that it is known as the *Valley of the Hammock; Momotombo*, *Negro* and *Santiago* volcanos in Nicaragua; the steaming grounds of *Rincón de la Vieja* and tlie peaks of *Pow* and *Irazú* in Costa Rica. to name only a few from a long catalogue of tectonic and thermal manifestations. We know that they were of importance to the primitive settlers in tlir region because close to the manifestations. it is frequent to find offerings dating from the very early Preclassic Period.

4. INFLUENCE OF GEOTHERMAL ENERGY ON MESOAMERICAN MAN

Weathered volcanic soils, because of their enhanced fertility and ability to retain humidity, allow the growth of a dense and varied flora, which supports an abundant fauna. These elements make the area attractive to people, from nomadic hunter - gatherers to intensive farmers (Grayson and Sheets. 1979). The end result is that people concentrate around places with geothermal activity and, in so doing, expose themselves to potentially disastrous volcanic eruptions or earthquakes. The impact of these events on the environment and the societies established around their foci is variable. depending on the magnitude of the event and its precise nature and characteristics, but also on components related to the social organization of the settlers, their hazard perception, land use, and so on.

The primitive Mesoamerican societies were no exception, as exemplified with regard to the eruptions of *Xitle*, *Arenal* and *Ilopango*. The latter's eruption, in the fifth century B.P., ended the southeast Mayan civilization. and allowed people from northern Guatemala to seize their lucrative trade routes

Some Mayan lowland sites, like *Barton Ramie* in Belize, apparently received refugees from that event, and their sudden arrival may have produced not only agricultural adaptations. but greater political centralization and class differentiation as well (Sheets, 1979). Also, the Mava living 1.400 vears ago in *Cerén*. in what is now El Salvador, experienced what the materialization of these risks may be. A rapid series of explosive eruptions took place within 2 km of their village when rising magma encountered ground water. Buildings were demolished and then buried by ash and pumice. Details of domestic Mayan life were preserved: dirty dishes and pots full of food, and footprints in ash, suggesting they fled the town (Fink, 1993). These cases agree with the studies made in Costa Rica, by Sheets (1984) at *Arenal*, and Hurtado de Mendoza and Alvarado (1988) at *Miravalles*, regarding the possible influence of their eruptions on the socioeconomic, agricultural and artisanal development of the precolumbian local inhabitants. They have shown the existence of *expulsive processes* for human population, during and immediately after main volcanic episodes, followed by inverse processes of the *attractive* type.

Besides anthropological evidence, we have direct indications of the awareness the precolumbian Mesoamerican inhabitants had of geothermal phenomena. For example, many volcanos of the zone still bear autochthonous names: *Iztaccíhuatl* (iztac = white, huatl = woman), *Popocatépetl* (popoca = steaming, tepetl = hill), *Citlatépetl* (citlali = star, tepetl = hill), etc., and some of the extant codices, like the Nutall, the Tellerianus Remensis and the Quauhtinchán, bear their representations in hieroglyphics. Besides, many towns have Indian names referring to some geothermal characteristic of the place. For example, *Atotonilco* (a[tl] = water, totoni][li] = hot, co = place) signifies *" place in rhr hor water"* in nahuatl. In Mexico. there are about 25 villages with that locative. Also, there is a town named *Puruándiro* and a zone called *Pathé*; both names have a similar meaning in purépecha and in otomí, respectively.

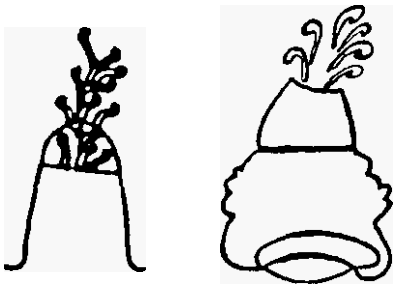

Figure 1. Hieroglyphs for *Popocatépetl*.

5. INFLUENCE OF GEOTHERMAL MANIFESTATIONS ON MESOAMERICAN RELIGION

The overpowering magnificence of the geothermal phenomena and their connections with areas of bounteous resources, or else with death and devastation, made the primitive inhabitants of Mesoamerica quite naturally associate these manifestations with powerful gods that had to be propitiated. It is then a most frequent occurrence to find archeological caches near places of geothermal activity. So, for example, Stone (1941) describes the place called *Peroles Calientes*, in the *Black River Valley* on the northern coast of Honduras, which "must have been a very important one to the natives, for the quantity of pottery to be found there is immense. Food seems to have been the principal article offered to the *hor water gods*, because pot upon pot was placed upright, some within others," with the best pieces directly positioned under the hot waterfall. At *Miravalles* volcano in Costa Rica, the remains of an offertory were discovered close to a lava outcrop on its southern flank, to which the primitive inhabitants held a reverential attitude.

An additional example is that of the cache found under a stratum of volcanic sand on the slopes of *Irazú* volcano, also in Costa Rica. It amounted to more than 400 objects. including male and female figures, offering tables. heads. etc.. made of lava or volcanic stone. plus some 100 wood articles, preserved from weather and insects by the laver of volcanic sand (Stone. 1941).

These examples do not show us whether these people believed that there was a god residing at the place of the geothermal manifestations, or if they worshiped the phenomena. An evolution in thin sense is to perceive the gwthermal manifestations as the attributes of a god or that such a god represents the forces and elements involved in the phenomena. This is what we have with *Huehuetéotl,* the oldest of the gods. who controlled fire from his dwellings at the "world's navel" that is, the Earth's center, or with *Xiutecutli*, who united the fires of Earth and Sun. *Tláloc* was the rain god, but he could bring volcanic eruptions also. so he could produce rains of water or rains of fire. *Tlazoltéolt* was the goddess of carnal love and of natality, but she ruled over steam baths as well. It must be kept in mind that these deities were not perceived as clear cut "individuals," but as "complexes." of closely related gods or goddesses and their attributes.

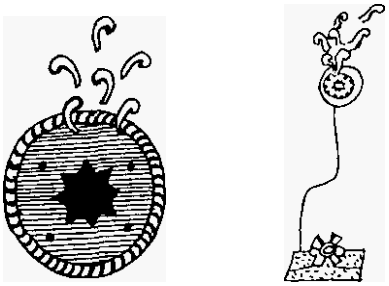

Figure 2. The first hieroglyph stands for *Citlatépetl*. The second one reads *"Citletépetl was smoking when rhr earth trembled."*

6. RAW MATERIALS OF VOLCANIC ORIGIN

Many of the artifacts manufactured by the early Mesoamericans were made out of volcanic materials: silex. flint, basalt, and very especially, from obsidian and jade. Obsidian, being a glass that fractures in flakes with sharp edges, was particularly good to make knives, spear or arrow points. scrapers, needles and similar utensils. It is interesting to note that the nahuatl name fur obsidian is *itztli*, which means knife also. Obsidian blades have been found practically in all Mesoamerican sites. When obsidian was not locally available, it was traded, as the following examples show. At *Chalchuapa*, the remains of a large shop for the manufacture of knives were discovered. However, the obsidian nuclei found there are from *Ixtepeque* volcano in Guatemala. some 50 km away. Also, tlir obsidian knives found at *Copán* were imported, because no natural deposits of obsidian are known in its environs.

Jade was considered the most precious of all materials by the Maya and. quite properly, it was the precious stone of the fire god, *Itzamna*. Rather than lose the huge jade necklaces with which they adorned themselves by burying them with the dead, good pieces were handed down from generation to generation, which explains why little jade has been found in many of the tombs uncovered.

Moreover, when for reasons unknown to us the Mayans quietly and orderly abandoned *Copán*, thcy took their precious jade with them (Longyear, 1952). Something similar occurred in *Quiriguá* (Sharer. 1979), whose last ruler *(circa* 1200 B.P.) was named *"Jade Sky."* If Jade was an adequate name for a sovereign. or for a goddess, as is the case with Chalchiutlicue *(Jade Skirt)*, we must conclude that the material was very esteemed. Also, historians suspect that the motive for the Mayans founding colonies in the southwest lowlands. in the classical period, would have been to secure the control of the *jade* ***Motagua way,*** besides procuring Other local resource).

Lava and volcanic stone were used widely. as is exemplified by the cache, previously mentioned, on the slopes of the volcano *Irazú* and by the tombs with lids made out of laminar formations of lava *(lajas)* and the sepulchral estellae carved on lava with columnar fractures that were found on the flanks of *Miravalles* (Ryder, 1983).

Figure 3. Hieroglyph fur *Atotonilco*. It depicts a pot placed over fire.

7. INDIRECT REFERENCES

Spanish missionaries and chroniclers have left us transcriptions of Indian legends and traditions that they collected, in many of which one can find references to geothermal phenomena. For example, according to a myth recounting the migration of the people, that were searching for ***Tamoanchán,*** they *"were looking for mountains:* ***some white mountains*** *and some smoking mountains."* Would it be too farfetched to interpret it as that they were consciously trying tu secure for themselves a country fertilized by previous volcanic deposits and well irrigated by snow water? In another example, a number of writers from the beginning of the Spanish Colony. like Fray Bernardino de Sahagún (1534) and Diego Muñoz Camargo (1540), tell in very similar words of signs that forewarned Moctezuma of the coming of the Spaniards. One of these omens, tlie *Fifth Prodigy*, seems to correspond to a phreatic explosion ill the lake that was located in the outskirts of the Aztec capital *Tenochtitlán*, now Mexico City (Burgassi *et al.*, 1992).

The Aztecs believed that our world has passed thorough different epochs, called ***"Suns,"*** and that each of the previous ones has ended in a cataclysm. The last they knew. which presumably is the one in which we are living, was the *Fifth Sun*, and they said that *"in it, there* will *be earthquakes."* The previous one, tlic *Fourth Sun*, was the ***"Sun*** *of the Fire* ***Rain. And*** *it happened that during it, it rained fire.* ***And*** *those who were living at the time burned out. And at the* ***time,*** *it rained* ***rand*** *also. And they say that* ***in*** *that Sun, it rained the pebbles* ***that we*** now *see, that the* ***tezontle*** *stone boiled and that the* ***boulders*** *reddened."* It is hard not to conclude that we have here the description of a devastating volcanic event, as narrated by a frightened survivor, and later transmitted from mouth to mouth fur generations.

8. THE POSTCOLUMBIAN ERA

The Mediterranean basin has been tectonicaly active since the most remote antiquity, so the tirst Europeans tu arrive to Mesoamerica were already acquainted with geothermal manifestations, either first-hand or by reference. But probably. they had never been exposed to phenomena of the magnitude and frequency of those they witnessed in the New World. Their reaction was awe, as can be seen in the books of Juan de Cárdenas (1591). Bernal Díaz del Castillo (1568), López de Gomara (1552) and Suárez de Peralta (1589). An interesting narration is the one by Pedro Castañeda Nájera (1560) about the discovery of the geothermal manifestations adjacent to ***Laguna Vulcano*** by the expedition of Melchor Díaz. This area is located near the *Cerro Prieto* power plants. tlie largest geothermal installation in Mesoamerica. According tu the chronicler, *"... as* ***they were walking,*** *they arrived into dunes of boiling ash, so that nobody could* ***advance*** *through them... the land trembled ..."*

Sometimes, the Spanish writers tried to provide an explanation of the events' origin, in many cases, of real scientific value. as happens with the description of the geothermal gradirnt offered. probably fur the first time in history, by Gonzalo Fernández de Oviedo (1526). In other instances, they did not content themselves with theorizing about the geothermal phenomena. but sought to gain first-hand knowledge of them Just to name a few examples, we will mention the attempts to sample the lava of the *Masaya* volcano by Fray Blas de Iñesta in 1550, or the different ascents to Popocatepetl while in eruption, the first one by Diego de Ordaz and two of his soldiers, then the unsuccessful one by Antonio de Betanzos and the one by Fray Bernardino de Sahagún, who accompanied by four or five Spaniards, ***"ascended*** *to its very mouth ..,* ***and*** *there were very big* ***James. and*** *it* ***boiled*** *as a cauldron, and this bad thing expelled a* ***large amount*** *of sulfur stone ... and, from very far away, one sees the* smoke ***leaviny, as*** *in a furnace, except that in a very huge* ***amounr."***

The influence of geothermal events an the lives of Mesoamerica's inhabitants continued after the Conquest: on repeated occasions, earthquakes and related catastrophesdemolished colonial cities. That is the case with *Antigua* or *Santiago*, as it was originally known, that was destroyed by earthquakes in 1773. so present-day Guatemala City had to he inaugurated the capital of tlie country in 1776. ***Cartago,*** the former capital of Costa Rica. was so ruined by an earthquake in 1841 that only 100 houses anti a church were left standing, and the capital was then established in San José. In a more recent example, after *Sun* ***Salvador.*** in El Salvador, war destroyed by an earthquake in 1854, the capital was moved to Santa Tecla, which then took the name of Nueva San Salvador. Yet, illustrating the principle that people dismiss the risks from a potentially disastrous event if they are obtaining some benefit, the nation's capital was relocated at San Salvador again. Tlie city has suffered heavy damage from earthquakes in 1873 and 1907. Special mention shall he made of *Mount Pelée*, in the Caribbean island of Martinique. After two innocuous active events in 1792 and 1851, il violenllyerupted on May 8th of 1902, completely destroying the city of Saint Pierre and killing 30.000 people.

Regarding the exploitarion of minerals or heat connected with geothermal manifestations, we know of only a few but notable instances, the most famous one being the (miningof the *Popocatépetl* sulfur deposits. Suárez Peralta reports that the Indians used to obtain this material from the volcano skirts, and it is a legend that Diego de Ordaz got from its crater the sulfur needed by Cortés' army to manufacture gunpowder. The fact is that these deposits were mined until February 19 of 1919, at which date, tlie company working them exploded a too largr dynamite load. The explosion provoked

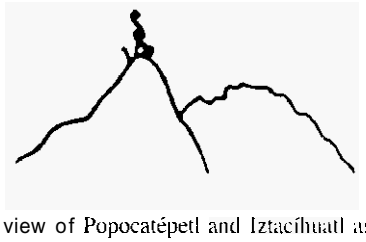

Figure 4. A view of Popocatépetl and Iztacíhuatl as shown in the Codex of Cuauhtinchán.

an earthquake and an eruption, resulting in the death of 17 workers. In another curious case, the Nicaraguan authorities extended a permit in 1551, to one Juan Alvarez, to excavate the volcano *Masaya* and extract the melt of *metal* that. he thought. was collected in the depth of its crater. Indeed. thermal waters were used for their therapeutic properties by original settlers and Spanish conquerors alike. For example, the *Baños del Peñón*, located in tlie boundaries of the present-day Mexico City airport, were renowned for healing many ailments

9. SUBSEQUENT TESTIMONIES

During the last century, and notwithstanding tlie problems that the Mesoamerican region had to endure. many foreigners visited it, for different reasons, and many of them have left reports about its notable volcanic and seismic activity. For example, Henry Ward (1827), the first British ambassador to Mexico, confirms that *Popocatépetl* is an active volcano and speculates on the effects of a sudden thawing of its snow cap due to a "*violent eruption.*" He offers, as endorsement to his ominous conclusions, tlie report of a similar event witnessed by Humbolt at *Cotopaxi* in 1802. In the course of a trip that Mr. Ward made in 1827, to inspect mines in the central pan of Mexico, he crossed the *Pathé River.* Around it, he noticed many "*hotsprings of mineral waters from which dense sulfurous vapors rose.*" Precisely in this area. the first geothermal power plant of Mesoamerica was installed in 1959.

Although there are inany other references tu the geothermal phenomena of Mesoamerica published in the XIX Century, we will end our report mentioning the study on "Les Geysers de Ixtlán" that Paul Waitz presented to the 10th International Geological Congress in 1906.

10. CONCLUSIONS

The distinct manifestations of terrestrial heat: hydrothermalism, volcanic eruptions. earthquakes, igneous mineral outcrops and so on, have always affected in a definitive form the lives of Mesoamerica's inhabitants. At a fundamental level, the existence of geothermal activity in a zone can decide whether its occupants will live or tlir. Rut geothermal manifestations' influence has also been present in a less categorical manner. It can affect utilitarian aspects only, as when people profit from the increased fertility of volcanic soils, exploit igneous materials or employ hot springs to bathe or heal. Though it can act on a nonmaterial plane also, fostering the advancement of scientific theories to explain geothermal phenomena, proposal of philosophical developments related to tlir Earth's lhrat in some general way, or creation of complete plutonic theogonies.

In recent years, specialists of diverse disciplines, but mostly geologists or engineers related to geothermal exploitation, anthropologists, and science and technology historians have advanced studies on this subject, and thcre is a growing bibliography. We hope that this Congress. in which a complete session has been allocated tu the history of man's relationship with geothermal energy, assists in quickening the evolution of this most interesting subject.

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