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HYDROTHERMAL KAOLINIZATION IN MICHOACAN, MEXICO

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Abstract—Active kaolinization of middle Tertiary obsidian and rhyolitic breccia in the San Andres range is effected by sulfurous hot waters and hydrous vapors emitted as springs, fumaroles, and geysers. The alteration preserves original rock textures and forms conspicuous aureoles around the hydrothermal vents, which shift about with slumping of the saturated clay. Systematic exploration by 87 test pits with maximum depth of 45 ft permitted inspection of the kaolin in place, and furnished bulk samples for laboratory work. Besides kaolinite, the clay contains unevenly distributed cristobalite and alunite, and traces of mercury. The natural brightness of the pure kaolinite approaches 90 if unstained by weathering, but little of it is pure. The yield of paper-coating fraction is small, and the composition and behavior in slurries are nonuniform. Most of the kaolinized material in the hydrothermal deposits is soft. Some, however, is hard and rock-like. Similar material occurs in clastic sediments of late Tertiary age, suggesting that the hydrothermal activity began at least as early as the Pliocene.

INTRODUCTION

KAOLIN deposits of mining interest occur in association with thermal-water activity in the San Andres Mountains of northeastern Michoacan, Mexico. The mountains have a maximum elevation of about 11,700 ft, and the kaolin deposits are in the northern part of the range at an average elevation of 9000 ft. The area is reached by unimproved road extending 18 miles northward from a point 4 miles west of Ciudad Hidalgo, a town 130 miles northwest of Mexico City (Fig. 1). A small hot-spring resort known as Los Azufres is located about 5 miles by road south of the principal kaolin deposits.

The deposits were examined during the exploration and evaluation of the kaolin resources for possible use in the paper industry. Although no analytical data from the deposits are available, data on similar materials elsewhere in Mexico have been given by Keller (1963) and by Keller and Hanson (1968). Field observations had the advantage of systematic excavation on a grid

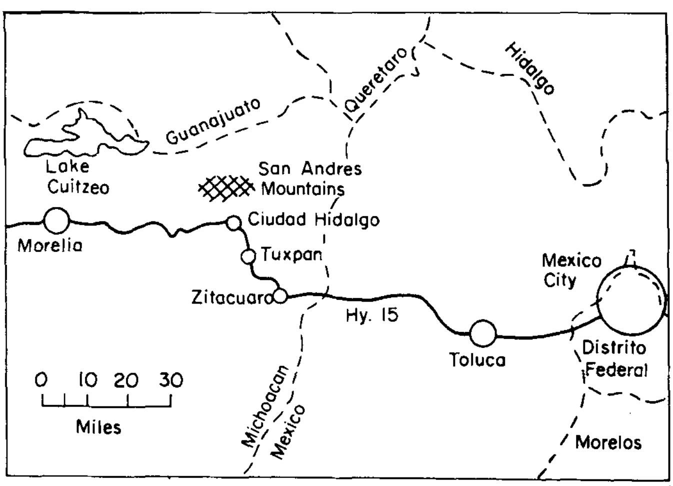

Fig. 1. Index map showing location of the San Andres Mountains.

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pattern in four deposits in an area about half a mile in diameter. The environment of current thermal-water alteration reduced the necessity for genetic speculation.

GENERAL GEOLOGY

Geologic conditions were studied along various routes traversed in the San Andres area, and were correlated with the geology shown on the editions of 1960 and 1968 of the Geologic Map of the Republic of Mexico. In the opinion of the writer, the edition of 1960 is more in accord with the conditions observed, and it designates as middle Cenozoic the great pile of volcanics constituting the principal bulk of the San Andres Mountains. The volcanics are best exposed in the northern and western parts of the range, and all thermal-water activity that was seen occurs in these parts.

Resting upon the volcanics is a thick series of coarse, clastic sediments designated on the same map (1960) as upper Cenozoic. These are best exposed in the southern and eastern parts of the range. They are sharply bedded, noticeably sorted and graded, well compacted, folded, faulted, and are probably Tertiary (Pliocene) rather than Quaternary in age. These clastics include thick beds of water-worn kaolinitic materials similar to those in the kaolin deposits described herein. Reference to these materials is made at the conclusion of this paper.

THE THERMAL WATERS

Heated waters and hydrous vapors are emitted at the surface in this region as numerous springs and fumaroles, and a few low-intensity geysers (Fig. 2). These emissions were seen only in association with volcanic rocks, but they occur throughout an area of several square miles. Their alteration effects are called hydrothermal although the term commonly implies reactions at depth, and at pressures developed through the confinementh of depth. The surficial activity in the San Andres area, however, is evidence of deeper reactions at higher temperatures and pressures, and is therefore at the terminal stage of a declining hydrothermal sequence.

The hot springs have white, kaolinitic aureoles (Fig. 3) in which alteration and saturation are so thorough that walking is unsafe. A characteristic feature is the gradual shifting of the orifices through which the waters and vapors emerge, due to the slumping of ground as leaching proceeds. This slumping has choked some vents entirely, leaving, in effect, fossil springs. Where the area around a large fumarole has undergone general collapse, the broken ground continues to emit vapor in a manner resembling a brush fire.

There are no data regarding the deeper reactions or the source of the water, and the only available data on the thermal waters are in a paper by Blásquez (1961), which records a temperature of 85·5°C for two springs near the kaolin deposits, and a range of 32°–52° for ponds fed by such springs. Table 1 lists analytical data of Blásquez for waters in the vicinity of the deposits. The SO_4 values are relatively high, but it is doubtful that other values are genetically significant because the waters have passed through a long column of hot, saturated rocks in various stages of active leaching. Their composition when emitted at the surface is undoubtedly different from the composition that initiated the process of alteration at depth. Although Cl and SO_4 may be attributed to a volcanic source, the alkali and alkaline earth metals and SiO_2 are more likely to have their source, at least in part, in the leached rocks.

RELATION OF LITHOLOGY TO ALTERATION

Early in the field work it was recognized that the alteration of bedrock to white kaolin is in progress only where the thermal waters are in contact with volcanics of salic composition. Rocks of intermediate to femic composition yield dark clays with the high shrinkage characteristics of montmorillonite (Fig. 4).

The close association of kaolinization with the

Table 1. Selected analyses of San Andres thermal waters in mg/1. (Data from Blásquez (1961)

Cl	SO_4	Na	K	Ca	Mg	Fe	SiO_2	Residue	pH
	181	60	19	9	2	2	236	761	
10	31	8	1	8	2		134	271	
21	618	70	50	3		4			
21	258	38	55	15					
7	44	14	13	2					
	146	18	6	22	11	81	168	816	2·9
596	514	665	52	28			61	2310	8·3
21	96	100	10	14			148	587	6·1

Fig. 2. Maritaro geyser, situated in a heavily alluviated stream bed $\frac{3}{4}$ mile from the kaolin deposits.

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Fig. 3. Steaming spring with kaolinized aureole, on the north slope of Cerro del Gallo.

Fig. 4. Active mud-pot near Maritaro geyser. Note high shrinkage of the drying clay.

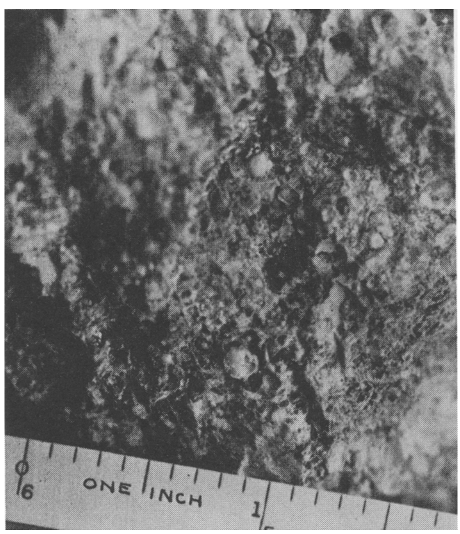

Fig. 5. Partly kaolinized obsidian, showing control of alteration by concentric perlitic cracks.

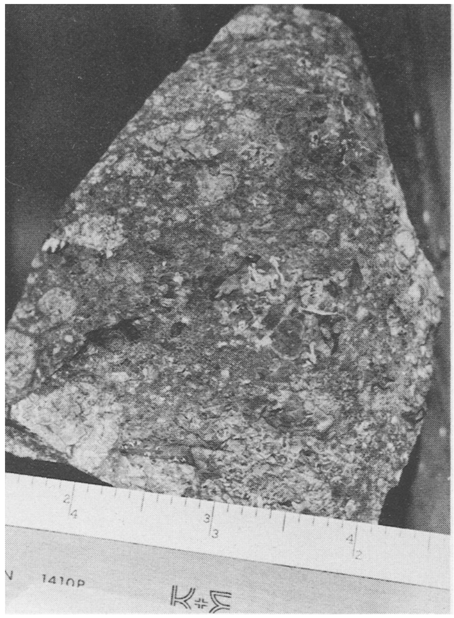

Fig. 6. Fresh rhyolitic breccia with spherulitic lithic fragments, and whole and fragmental spherulites in the matrix.

Fig. 7. Residual masses of partly altered bedrocks in kaolinized ground.

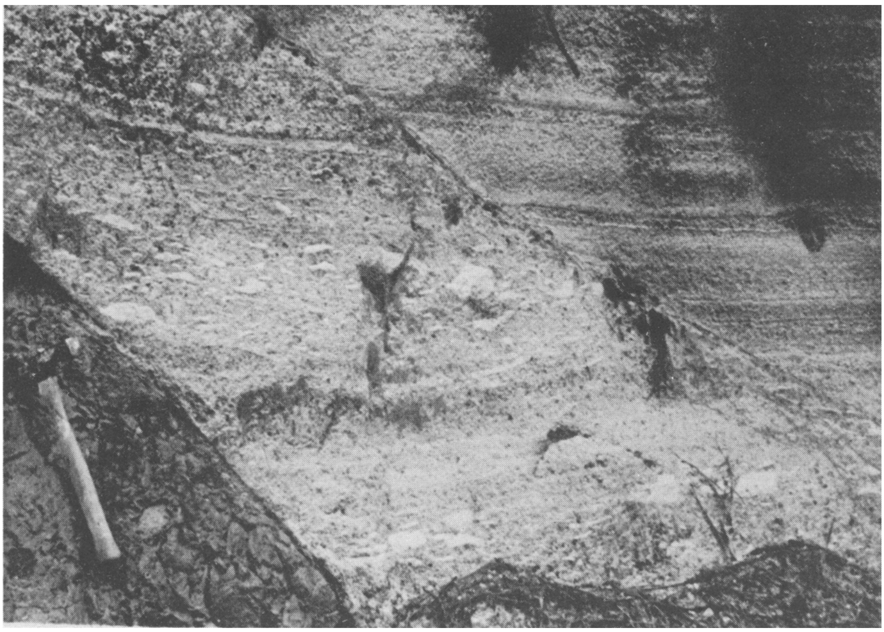

Fig. 8. Coarse, kaolinitic clastics in the sedimentary series overlying the San Andres volcanics

salic rocks is best shown on the crest and slopes of a ridge known as Cerro del Gallo. The fresh bedrocks there consist of volcanic glass (obsidian) and rhyolitic breccia. Alteration of the obsidian proceeds along perlitic cracks (Fig. 5), leaving smaller and smaller spherical residuals of the obsidian in the newly formed kaolin. The fresh rhyolitic breccia (Fig. 6) contains lithic fragments and many whole and fragmental spherulites. The breccia texture, even the form and radial crystalline structure of the spherulites, is preserved in detail in kaolin formed from this rock, a feature strongly supporting the conclusion of Keller (1963) that such alteration involves little bulk volume change. Attempts to record the details of the pseudomorphs in photographs were not successful.

THE KAOLIN DEPOSITS

A total of 87 test pits on systematic grids in four areas penetrated the deposits to a maximum depth of 45 ft. The overburden is negligible, but some difficulty was encountered with residual masses of partly altered bedrocks (Fig. 7). These occur at random horizontally and vertically throughout the deposits. Erosion of the clay has left such masses of various sizes abundant on the surface, where their accumulation superficially resembles gossan deposits. Below the surface, these residuals are least abundant where alteration is nearest complete, constituting 5·5 per cent by volume of the ground explored.

X-ray diffraction work on selected samples revealed a mixture of kaolinite with cristobalite and alunite, the proportions varying widely, and the behavior of slurries in the laboratory was correspondingly nonuniform. Schoen and White (1969) report a genetic relation between alunitic kaolin and the water table at Steamboat Springs, Nevada, but there is no similar relation in the San Andres area. Although the ground was explored throughout a vertical range of about 300 ft, from the crest of a ridge to the lower slopes, it was found everywhere to be relatively dry. The only high moisture content occurs immediately adjacent to the hot-spring channels. Elsewhere, there is no water table and no evidence that one has existed in the past. Because of high altitude and sharp relief, the hot springs and their narrow zones of saturation are drained by surface runoff. Deep pits dug near such runoff were dry.

The crude kaolin has a natural brightness (percent reflectance) of 90 if free from mineral impurities including supergene stains. The average yield of minus 325 mesh material from the crude samples was 75 per cent, but fractionation below this level showed erratic particle size distribution. Yield in the paper-coating range varied between 9 and 49 per cent of total crude, averaging only 16·6 per cent on a specially selected composite sample. Nearly half of this coating size fraction, in all of the crude material prospected, is nonfluid in slurries of 71 per cent solids. Cristobalite is only partly rejected by fine fractionation, resulting in high values in the Valley abrasion test commonly used in the paper–clay industry.

Mercury is detectable in the kaolin even where there is no visible trace of it. In nine specially prepared fractions averaging mostly -1μ in particle size, spectrographic examination found mercury in amounts up to 0·005 per cent. Three samples showing a few bright red stains yielded values of 0·030, 0·035, and 0·16 per cent Hg by the same method, but these values are exceptionally high.

DURATION OF THE HYDROTHERMAL ACTIVITY

The kaolinized materials derived from the volcanic rocks range from very soft, where mining has been attempted, to moderately hard in many other places. It is not known whether this difference is controlled by degree of alteration or by the specific nature of the original rock, but the harder material responds to erosion more as a rock than as a clay. It yields fragmental detritus, and the fragments are strong enough to withstand abrasion.

This feature helps to account for the presence of kaolinitic material (Fig. 8) in the upper Cenozoic clastic series referred to in the section on general geology. Kaolinitic pebbles in those sediments have retained their sharp outlines, showing no tendency to shrink under the influence of supergene leaching, nor any collapse under load. Consequently, they were deposited with their present form and essentially their present composition, and the composition is similar to that of the kaolinitic material now forming in the hydrothermal environment.

Although the hydrothermal deposits are relatively numerous, they are not of sufficient volume to furnish kaolinitic material on a scale adequate for such thick beds as those of the sediments, regardless of the rate of erosion. Contributing to the disproportion is the fact that most of the material in the present deposits is too soft to yield coarse sediment.

The large volume of the coarse sediment requires, therefore, a late Cenozoic source of material of proportionate extent, indicating that earlier hydrothermal deposits must have been larger and more numerous than those of the present. It follows that the current hydrothermal activity may be only the waning stage of a larger episode that began in late Tertiary time.

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Résumé—La kaolinisation active du breccia obsidian et rhyolitique de moyen tertiaire dans la chaîne de San Andres est effectuée par des eaux chaudes sulfureuses et des vapeurs aqueuses emises en tant que sources, fumerolles et geysers. L'altération préserve la texture originale des roches et forme des auréoles notables autour des offices hydrothermique qui se transforment avec l'effondrement de l'argile saturé. Une exploration systématique dans 87 puits d'essai, ayant une profondeur maximale de 13,70 m a permis une inspection du kaolin sur place et fournit des échantillons en volume pour les travaux de laboratoire. A part le kaolin, l'argile contient du cristobalite, de l'anulite et des traces de mercure réparties d'une façon non uniforme. La luminosité naturelle du kaolin pur approche de 90 s'il n'est pas souillé par les intempéries, mais une petite quantité seulement se trouve à l'état pur. Le rendement d'une fraction d'enduit sur papier est infime et la composition et la comportement dans les boues ne sont pas uniformes. En grande partie, le matériau kaolinisé dans les dépôts hydrothermiques est mou. Toutefois, certains matériaux sont durs comme de la roche. Un matériau similaire se trouve dans les sédiments clastiques du dernier tertiaire, ce qui suggère que l'activité hydrothermique a commencé au moins dès le pliocène.

Kurzreferat—Aktive Kaolinisierung mitteltertiärer Obsidian und Rhyolith-Breccien in den San Andres Bergen wird durch die als Quellen, Fumarole und Geyser entwickelten schwefligen Heisswasser und wässrigen Dämpfe bewirkt. Die Veränderung erhält die ursprünglichen Gefüge und bildet deutliche Aureolen um die hydrothermischen Schlote, die sich beim Rutschen des gesättigten Tones verschieben Die systematische Erforschung durch 87 Versuchsschächte mit einer Höchsttiefe von 45 Fuss ermöglichte eine Besichtigung des Kaolins an Ort und Stelle, und lieferte Proben für die Laboratoriumsforschung. Neben Kaolinit enthält der Ton ungleichmässig verteilten Cristobalit, Alaunstein, sowie Spuren von Quecksilber. Die natürliche Helle des reinen Kaolinits nähert sich 90 wenn unverfärbt durch Verwitterung, aber es ist nur wenig reines Gestein vorhanden. Die Ausbeute an Papierbestrich Fraktion ist klein, und die Zusammensetzung und das Verhalten in Aufschlämmungen ist ungleichmässig. Der Grossteil des kaolinisierten Materials in den hydrothermischen Ablagerungen ist weich. Manches jedoch ist hart und felsartig. Ahnliches, in klastischen Ablagerungen des Spättertiär vorkommendes, Material deutet darauf hin, dass die hydrothermische Aktivität zum mindesten zur Zeit des Pliozäns begonn en haben muss.

Резюме—Активная каолинитизация среднетретичных обсидианов и риолитовых брекчий в хребте Сан Андрес вызвана воздействием сернистых горячих вод и паров воды, выделявшихся источниками, фумаролами и гейзерами. Это изменение не затрагивает, однако, текстуры первоначальной породы и образует заметные ореолы вокруг гидротермальных выходов, которые смещаются с оползанием насыщенных водою глин. Систематическое изучение с помощью 87 разведочных выработок с максимальной глубиной 45 футов позволило получить данные о залегании каолина и получить валовые образцы для лабораторного исследования. Кроме каолинит галины содержат неравномерно распределенные кристобалит и алунит, а также следы ртути. Естественная белизна чистого каолинита, не окращенного продуктами выветривания, достигала 90, но такова лишь незначительная часть материала. Выход фракции, пригодной для покрытия бумаги, невелик, а состав и свойства смесей с водой неоднородны. Большей частью каолинизированный материал в гидротермальных месторождениях является мягким, но встречаются твердые и камнеподобные образцы. Аналогичный материал встречается в кластических позднетретичных осадках; это говорит о том, что гидротермальная активность началась, по крайней мере, уже в плиоцене.

Dr. Clarence S. Ross on the left making remarks after receiving the Distinguished Member Award. Dr. M. L. Jackson is on the right.

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