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KAOLINIZATION PROCESSES IN AN AREA OF SEGOVIA (SPAIN)

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ABSTRACT

In Vegas de Matute, South of Segovia, there is a kaolin deposit formed by weathering on Hercynian gneisses of the Spanish Central Massif, fossilized by the overlying Albian, which is also kaolinitic (sands and clays).

Mineralogical differences (clay and heavy minerals) and differences in kaolinite crystallinity make it possible to distinguish between both types of kaolin (residual and sedimentary), even though the Albian kaolinitic sands are derived from the erosion of residual kaolins formed on acid rocks of the Central Massif, such as those fossilized in this deposit.

Most of residual kaolin was probably eroded prior to Cretaceous times and the remaining kaolin was preserved as a deep crust because of poor drainage. The weathering profile is dominantly kaolinite near the top with the smectite content increasing with depth to a maximum of 60%. Some-time after the Cretaceous period some of the Albian kaolin was altered, in a basic environment, to smectite.

INTRODUCTION

Kaolin deposits formed "in situ" on silicic rocks by weathering processes are very limited in Spain, in spite of the fact that silicic rocks occupy a large portion of Western Spain. These extensive granitic and gneissic areas have supplied, during different geological ages, kaolinized materials that have given rise to kaolinitic sediments and at times to sedimentary kaolin deposits, proof that time after time these residual kaolinized rocks were eroded; however, at present several meters thick kaolinized weathering crusts can rarely be found.

The example given in this paper demonstrates the existence of a post-Hercynian stage of kaolinization on metamorphic rocks of acid character, which have been eroded to a great extent, but whose lowest levels have been preserved because of the overlapping of Cretaceous sediments. These sediments are kaolinitic in composition and are, ipso facto, the result of the dismantling of the kaolin crusts developed on those areas during the same period.

The Cretaceous kaolin facies (Weald and Utrillas, Lower Cretaceous and Albian, respectively), is widespread in Spain, with important deposits of kaolinitic sands in the Iberian Range (Cordillera Ibérica). However, these sands don't overlap the source area itself.

GEOLOGY

The deposit of Vegas de Matute is some 25 km south-east of the capital, Segovia. From a geological point of view, it is located in the narrow Mesozoic strip that borders to the north the larger part of the Spanish Central System *(Fig. 1)*. The Central

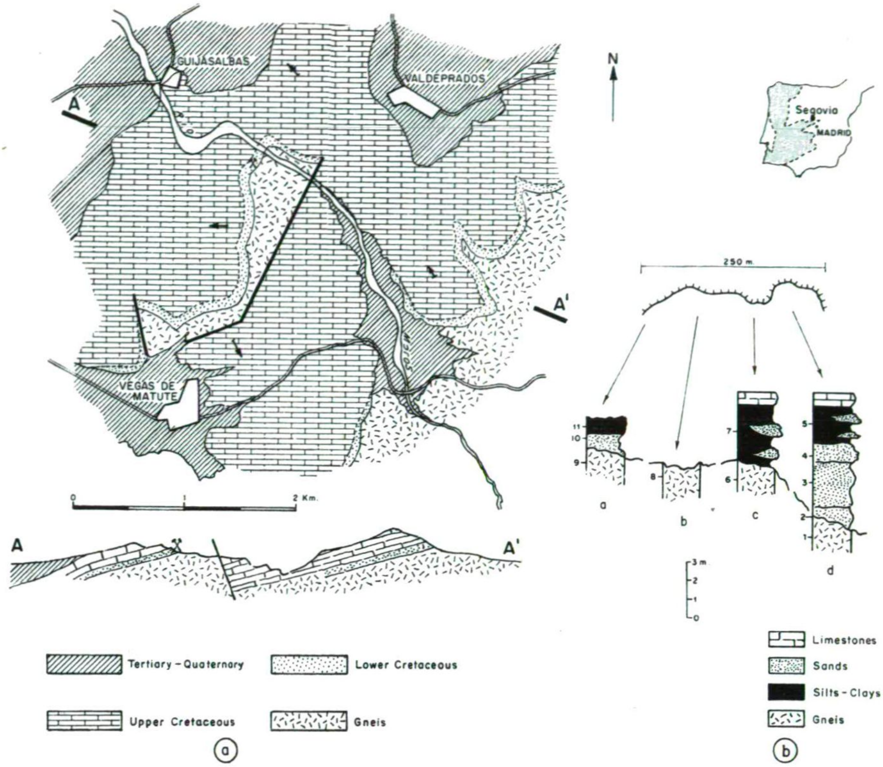

Fig. 1. The Vegas de Matute area (Segovia, Spain)
a) Cartography of the studied area and location of the kaolin deposit
b) Different sections along the kaolin deposit and sampling location

Massif is formed by metamorphic and plutonic rocks that extends eastward from the Portuguese frontier to the Iberian Range. The meridional and septentrional limits of the Central System are formed by Mesozoic and Tertiary materials that constitute the basins of the Tajo and Duero rivers, respectively. This kaolin deposit is located in the central part of the afore-mentioned mountainous range. The principal characteristic of this sector is its petrographic uniformity as well as the degree of metamorphism. The Central Massif is formed almost exclusively by catazonal gneisses, the 90% of which is of an 'augen' type, with large phenocrysts of potassium feldspar, and the rest corresponds to fine grained banded gneisses and gneisses with plagioclases interlayered in an 'augen' formation.

The gneisses were derived from pre-Ordovician rocks, which probably orginated during the Cambrian period. The metamorphic process that gave rise to these rocks belongs to the Hercynian and demonstrates characteristics which are similar to the intermediate type formed under low pressure conditions [MIYASHIRO, 1972]. A detailed study of the metamorphic rocks of the Central System [LÓPEZ RUIZ, *et al.*, 1975], enables one to observe, however, important variations in time and space as regards the metamorphism of this region, which lends support to the hypothesis of a plurifacial and polyphase metamorphism.

A Mesozoic and Tertiary cover is found on this crystalline substratum, bordering the entire Spanish Central System.

The Mesozoic lies above the gneisses, fossilizing an important paleo-relief, which explains why its thickness varies notably from one sector to another. Furthermore, the basement — in its uppermost part, represents an alteration which normlaly reaches a depth of 2 or 3 meters.

The Mesozoic cover is limited exclusively to the Cretaceous. The Cretaceous series consists in its lower part of detrial sediments (sands, silts and clays of a kaolinitic nature), whose thickness can attain up to 50 meters, although generally it is less. Compared to other areas, the detrital levels are considered to be from the Albian period. These detrital sediments resemble facies similar to fluvial and lacustrine environments. On the altered gneisses of the Vegas de Matute deposit there are detrital beds, with thicknesses not exceeding 8 meters. These are Albian layers which together with the altered gneiss, are exploited for kaolin. In the mine it is possible to observe how these detrital facies change frequently and abruptly in thickness and lithology *(Fig. 1b)*, as it is generally in the case of the Albian sediments of this area bordering the Central System.

A succession of Upper Cretaceous (Cenomanian-Turonian) limestones and marls overlies the detrital beds. More recent Mesozoic sediments than those described above are absent in this region.

Lastly, and also forming parts of the cover are Paleogene and Neogene sediments, which partially overlie the Cretaceous or the gneissic substratum. The Tertiary, exclusively continental in origin, comprises coarse detrital sediments in the lower portion, and sandy or clayey sediments in the upper portion. These materials thicken considerably toward the north.

The Hercynian orogenesis is not only responsible for the metamorphism that affected and originated the gneissic substratum, but it also produced the intense fracturing of the Paleozoic materials and plutonic rocks of the Central System. The Mesozoic-Tertiary cover was gently folded during the Alpine orogeny. The Alpine activity caused subsequent displacements and in some cases produced fracturing of the substratum, wherein the cover adapted itself to the movement or relief on the basement.

MATERIALS AND METHODS

The Vegas de Matute deposit has been sporadically mined. Its location is shown on the map in *Fig. 1a.* The open cut of the mine was sampled in detail and the sequence of materials established. Other profiles were also sampled outside of the active open-pit mine. The characteristics of these series and the sampling positions are shown in *Fig. 1b.*

The lack of lateral continuity of the detrital beds is to be noted; there is alternate overlapping, reflecting an enormous variation in granulometry (silt, sands, silty-clays, etc...), but the kaolinitic character is constant in every case.

A residuum of white clay is found occasionally with a thickness of 1 m on the altered gneisses which contains sandy ferruginous nodules with a diameter between 2 and 5 cms surrounded by a coating, like an aureole, of white clay.

These materials were studied by means of X-ray diffraction, petrographic microscopy, electron microscopy, and chemical analysis.

ANALYTICAL RESULTS

From the results of the mineralogical and chemical analyses, together with polytype determinations of the kaolinites of the different samples studied, (Tables 1, 2 and 3, and *Fig. 2*), it can be deduced that two types of materials exist:

a) More or less altered metamorphic materials, with variable content of feldspars, smectite and kaolinite, whose polytype varies from pM-T to T. Heavy minerals are present including zircon and tourmaline.

b) Sand and silt beds, rich in kaolinite and with variable content of anatase, goethite and hematite, and practically free of feldspars. Kaolinite in these materials represents disordered polytypes, fundamentally pM or pM partially ordered. The suite of heavy minerals is highly complex.

TABLE 1

Mineralogical composition (total)

Samples	q	c. m.	f	Others
1	60	25	15	—
2	40	60	—	—
3	60	40	—	—
4	>95	5	—	—
5	50	50	—	Anatase
6	50	20	30	—
7	85	15	—	Anatase
8	55	45	—	—
9	65	35	—	Goethite
10	90	5	—	Goet.-Hem.
11	70	30	—	Goethite

c. m. = clay min.; q = quartz; f = feldspars

TABLE 2

Mineralogical composition (< 10 μm frac.)

Samples	q	k	m	mo	Others	K. polyt.	H. In.
1	5	60	5	30	—	pM-T	0.54
2	20	75	<5	5	—	T	1.1
3	30	50	<5	>15	—	pM	n. d.
4	15	85	tr	tr	Goet	pM	n. d.
5	10	90	tr	—	Anat.	pM	0.36
6	10	25	10	55	—	pM-T	0.50
7	10	90	tr	—	Anat.	pM	0.28
8	20	75	<5	5	—	T	1.01
9	5	>90	<5	tr	Goet.	pM-T	0.55
10	25	50	—	10	Goet-Hem (15)	pM	n. d.
11	25	60	—	15	Goet.	pM	0.35

q = quartz; k = kaolinite; m = micas; mo = montmorillonite; k. polyt. = kaolinite polytype; H. In. = Hinkley Index

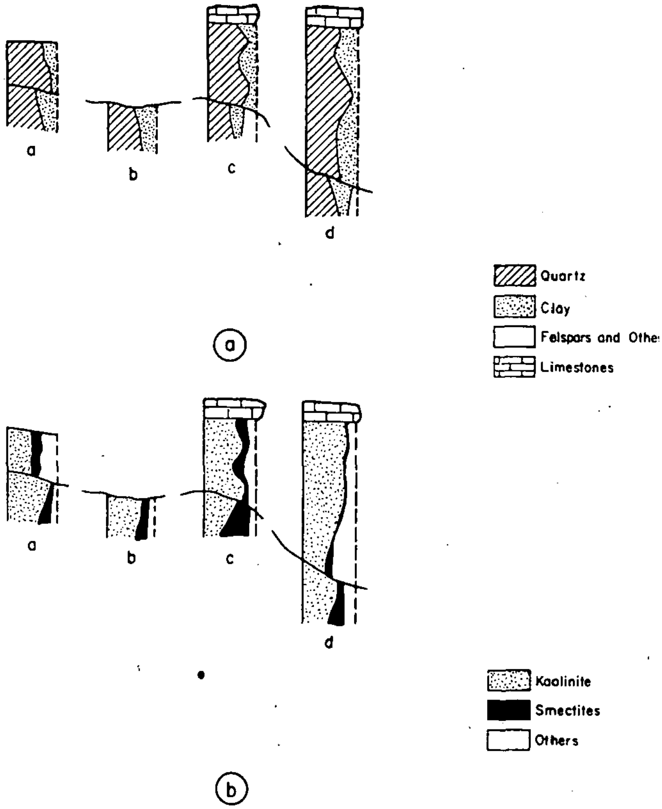

Fig. 2. Mineralogy of the kaolinized gneisses
a) $<10\ \mu m$ fraction b) total sample c. m. = clay minerals; q = quartz; f = feldspars; k = kaolinite; mo = montmorillonite; sam = sample number (see *Fig. 1b*)

The quantitative mineralogical analyses of these samples corresponding to temamorphic materials are represented graphically in *Figures 3a* and *3b;* said figures correspond to the less than 10 micron fraction and the total sample, respectively. In the first of the figures it can be observed that the content of non-clay minerals is clearly related to the degree of alteration which these materials have undergone, the alteration decreasing with depth. On the other hand, it can also be observed that the kaolinite and feldspar content is inversely related to each other, which is similar to that corresponding to kaolinite and smectite.

The attempt to correlate, graphically, the results of the quantitative mineralogical analyses of the samples belonging to the second type of materials is negative. This is because the materials in question present different granulometric characteristics and are distributed in a lenticular fashion throughout the entire sampled outcrop.

Data of particular interest are the absence of feldspars and the presence of heavy minerals not observed in underlying materials. The suite of heavy minerals most frequently observed were tourmaline, zircon, andalusite, staurolite, kyanite and rutile, and infrequently garnets, brookite and topaz.

With regard to the white clay beds with ferruginous nodules, the high content of well crystallized smectite (30%—50%) is to be noted, (Biscaye index), which represents an anomaly in the composition of the Albian materials of this region. The nodules contain about 30% smectite, while the matrix of the surrounding sediments contains as much as 60%. The iron content increases towards the interior of the modules, so that the aureole or crown appears white (1.38% Fe_2O_3) whereas the interior is red (3.70% Fe_2O_3).

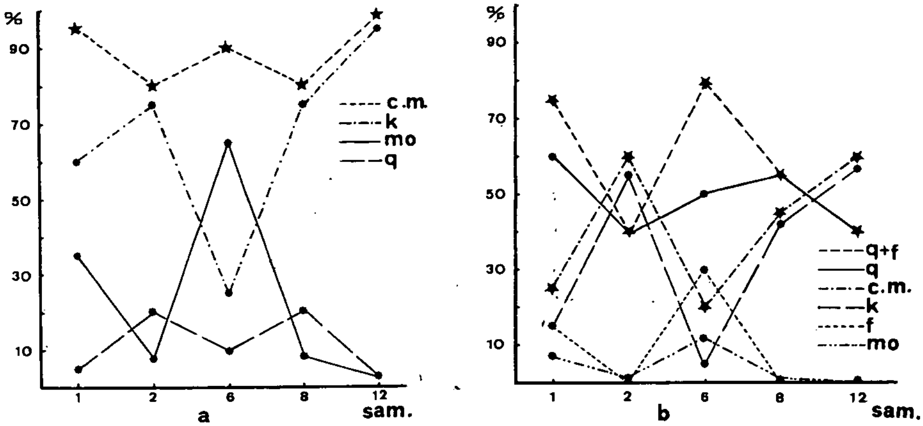

Fig. 3. Mineralogical composition of
a) total sample
b) $\lesssim$10 μm fraction in the same profiles as in *Fig. 1b*

TABLE 3

Chemical analyses (<10 µm frac.)

Samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	L. Ign.
1	57.30	32.61	0.47	0.01	0.19	0.20	2.50	5.35
2	56.28	31.90	1.00	0.03	0.13	0.90	0.52	9.04
3	57.25	36.50	0.48	0.18	0.25	1.60	0.36	3.10
4	55.29	37.06	0.60	0.28	0.33	0.32	0.76	5.16
5	50.39	35.70	0.70	0.42	0.19	0.11	0.67	11.73
6	52.65	33.27	0.52	0.25	0.54	0.26	2.11	10.30
7	49.37	36.41	0.64	0.12	0.26	0.34	0.43	12.25
8	50.48	35.69	0.40	0.14	0.26	0.29	0.67	11.99
9	49.92	37.21	1.66	0.09	0.23	0.17	0.38	10.21
10	51.60	35.23	3.20	0.50	0.41	0.12	0.96	7.87
11	49.46	33.65	1.84	0.25	0.39	0.06	0.95	12.37
Fe-Nodule	54.94	28.50	3.70	0.17	0.27	0.60	0.13	10.80
Matrix	55.02	29.20	1.38	0.26	0.27	1.00	0.22	12.58

DISCUSSION OF RESULTS

Subsequent to the Hercynian metamorphism of the region, in the area studied, two fundamental geological processes independent of each other took place. The first was the alteration of granites and gneisses by weathering processes which resulted in profiles *(Fig. 2* and *3)* with kaolinite dominant in the upper portion and smectite increasing in content toward the base up to a maximum of 60 percent. The second event was the erosion, transport, and deposition of the weathered crust resulting in Albian kaolinite sands, silts, and clays (Utrillas facies) in whuch the kaolinite is clearly an inherited mineral [LÓPEZ AGUAYO and MARTÍN VIVALDI, 1973].

The samples of the weathering crust were collected with reference to the gneissic surface and one can assume that they correspond to non-eroded crusts where drainage was deficient because the smectite content could be as much as 30 percent higher in the thin crust.

The weathering process affected micas, biotite, muscovite, feldspars and chlorite, and it was of a regional character [GALÁN and MARTÍN VIVALDI, 1975].

The Utrillas facies of the Albian are kaolinite sands alternating with silt and clay layers. The kaolinite in these sediments is inherited from the weathering crust and their genesis has been studied extensively by LÓPEZ AGUAYO and MARTÍN VIVALDI [1973], GALÁN *et al.*, [1975], and LÓPEZ AGUAYO *et al.*, [1971]. The kaolinite in the weathering crust is a well ordered type or only slightly disordered (T...pM-T) with particles ranging in size between 0.1 and 0.5 micrometers. In the Albian beds the kaolinite is disordered with particle size of less than 0.1 micron. SHUTOV *et al.*, [1966] and LÓPEZ AGUAYO and MARTÍN VIVALDI [1973] have indicated that transport processes disorder kaolinites. This present study shows that the kaolinite in the weathering crust is ordered and after erosion, transport and deposition in the Albian the kaolinite is disordered.

The heavy mineral suite of the weathering crust and the Albian beds also differ. In the weathering crust zircon and tourmaline are found, whereas in the Albian beds the suite is more complex with zircon, tourmaline, andalusite, kyanite and rutile common and with occasional grains of staurolite, garnet, brookite, and topaz also present. This indicates that the source area includes more than the weathering crust on the granites and gneisses in the immediate vicinity.

Another interesting point in the area studied is the occurrence and composition of the ferruginous nodules in the silt matrix in the Utrilla facies. From field observations these nodules are syngenetic and are interpreted as "armoured mud balls". The composition of these nodules is different from the silt, so the smectite content in their centre is much less than the smectite content of the silt matrix. It is suggested that much of the disordered kaolin in the silt matrix was altered to smectite after deposition by ground water percolation which had a basic pH. The ferruginous nodules were not attached in the interior but only the outer white skin was leached. It is also suggested that the circulating ground water and not only the transport could contribute to the disordering of the kaolinite, because the Albian kaolinites of the Iberian Range which are much further from its source area are characterized by a high cystallinity [GALÁN, 1976], may be because they don't overlap rocks of poor drainage like in this case.

CONCLUSIONS

i The kaolinites in the weathering crust and in the Albian sediments differ in crystallinity. In the weathering crust the kaolinite has a higher crystallinity and coarser in particle size. This difference is attributed to transportation and deposition because it is believed that the Albian kaolinite was derived from the weathering crust.

ii Some silt beds in the Albian contain ferruginous nodules and the clay in the interior of the nodules contains less smectite then that found in the surrounding matrix. It is suggested that high pH ground water movement through these silt beds altered some of the kaolinite to smectite and contributed to the disordering of the kaolinite although the fossilized weathering crust also contains increasing amounts of smectite toward the gneissic surface due to a deficient drainage.

iii This study of a localized area indicates that a weathering crust was locally preserved and that the kaolinites in the Albian sediments were derived from the weathering crust. A wider area should be studied to shed additional information on this problem of kaolin genesis of the Spanish Central Massif and the associated kaolinitic sediments.

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