Proceedings of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy

Held in Geneva
1 September - 13 September 1958

Volume 2
Survey of Raw Material Resources

UNITED NATIONS
Geneva
1958

A Contribution to the Knowledge of the Uraniferous Lutites of the Province of San Juan (Argentina)

By Victorio Angelelli and Armando Ortega*

During the prospecting work carried out in the Pre-Cordilleran zone of San Juan Province, marked radioactivity was noted in the areas of the alum-containing schists of Calingasta and Rodeo, as well as in those occupied by the black lutites of the eastern foothills of the Pre-Cordillera to the north of the city of Jachal.

This fact confirmed what was assumed in that connection, i.e., that these sediments, in particular those of Calingasta and Rodeo, are similar to those found in other countries in which the presence of uranium in small amounts had been determined.

Of these sediments, the best known are those of the area of Calingasta, owing to the fact that they contain soluble sulfates in their mass, such as epsomite, alunogen and pickeringite, in significant quantities, which accounts for operations on a certain scale for more than 20 years. It was first discovered here that the radioactivity of these alum-containing schists exceeded up to three times the background for the area (0.012–0.015 μr/hr).

As regards the geology of the zones covered by this investigation, there are several works of a general nature, but none of them deals in detail with the stratigraphy of these uraniferous sediments.[1, 2]

The facts presented herein regarding those alum-containing schists or lutites, the interest of which resides not only in the fact that they contain the above-mentioned salts, but also, and particularly in this case, in their uranium content, constitute only one contribution to their investigation, which will be greatly extended as new and better data become available.

LOCATION AND MORPHOLOGY

Geographically, the Pre-Cordillera of San Juan lies between parallels 29°30′ and 32° of south latitude and meridians 67° and 69°15′ of west longitude, continuing to the north into the province of La Rioja and, to the south, into the province of Mendoza.

The Pre-Cordillera covers in the province of San Juan an area of about 35,000 km², its maximum width being 150 km. On the west, it is limited by the vast longitudinal valleys of Rodeo-Iglesia, Calingasta and Leoncito, separating it from the ranges, which rise immediately to the west. On the east, the large valley of Guandacol-Bermejo separates it from the mountain system of La Huerta-Valle Fertil and from the intermountain valley located between the latter and the Pie de Palo system.

This Pre-Cordillera is made up of long and wide folds with maximum heights of 4300 m above sea level, which are separated by longitudinal valleys, some of them large. The valleys which precede the San Juan and Jachal rivers cut the structure from west to east like faulted mountainous blocks.

The areas considered in this work are (*a*) Calingasta, (*b*) Rodeo, and (*c*) the zone north of Jachal. The first is located opposite the town of the same name, 135 km by highway to the west of the city of San Juan; the second 60 km by highway west of the city of Jachal, or 10 km east of Rodeo; and, finally, the third at 70 km in a straight line to the north of Jachal, in the Guandacol zone (Fig. 1).

GEOLOGY

In order to place ourselves in the medium within which the lutites of interest to us are found, we give in the main outline the general characteristics of the San Juan Pre-Cordillera, and will then consider the geological constitution of each of the zones mentioned.

The Pre-Cordillera is made up of the following formations:

Cambrian-Ordovician: Marine sediments with a thickness of a few thousand meters. Caliches and dolomites, in part rich in fossils, and clay-containing schists, nearly always in abnormal contact due to considerable Tertiary and Quaternary tectonic movements, with Middle Paleozoic, and marine sediments. To the Ordovician sedimentation period (Llanvirnian and Caradocian) there correspond the alum-containing schists or lutites which are the subject of this study.

Gontlandic-Devonian: Marine layers represented by slates, sandstones and graywackes, folded and displaced.

Carboniferous: Mainly continental ground, with some marine intercalations, made up of sandstones and clays, with glacial materials (tilites).

Permian: Continental sediments, essentially sandstones with remnants of plants and clay banks.

Original language: Spanish.

* Comisión Nacional de Energía Atómica, Argentina.

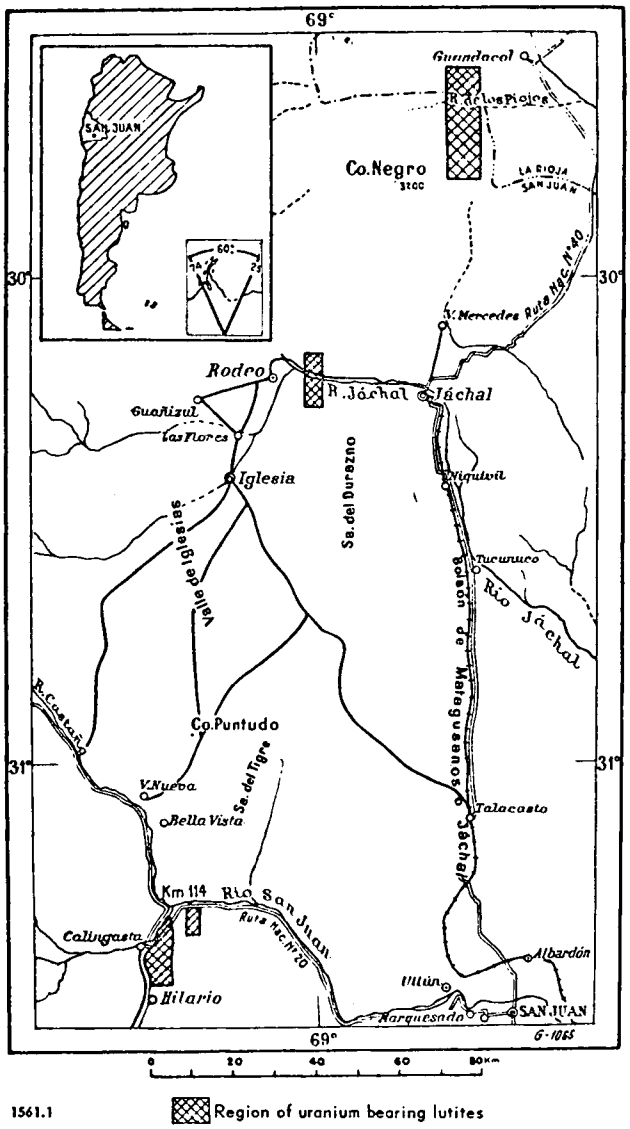

Figure 1. Location of uranium-bearing lutite zones of San Juan

Triassic: Porphyritic series represented by effusions of porphyres, porphyrites, agglomerates and their tuffs, and, above this series, continental sediments integrated by tuffs, sandstones and conglomerates.

Tertiary: Rocks which originate in a continental medium with different characteristics according to the groups. Conglomerates, sands and clays of yellowish brown and reddish colors. Mezosilicic effusions (andesites and dacites) and their tuffs.

Quaternary: Refill materials in the breaks and folds of the high pampas, with dejection cones and terraces. Accumulations of silt in valleys which have no drainage.

The structural characteristics of this unit are: orogenic movements (Taconic) at the end of the Cambrian-Ordovician sedimentation cycle; discordance between these terrains and those which are superimposed; diastrophism of some size at the end of the Devonian cycle (Mid-Devonian phase); intense movements at the end of sedimentation of the Permian (Appalachian phase); large hiatus during the whole of the period which corresponds to the Jurassic and Cretaceous; diastrophic cycle of the Tertiary-Quaternary in successive phases; accounts for the folding and intense breaking undergone by the Pre-Cordillera in its present configuration.

Calingasta

The lutite zone of this particular area is located in the eastern bank of the Calingasta valley, limited by its main drainage course to the Los Patos river and the high sierra of the Tontal to the east.

After contact with the terraced detritus on the edge of the river Los Patos and through the medium and low fold of the sierra mentioned, the marine sediments are mineralized with sulfates outcrop and, with a general NW–SE orientation, continue for about 20 km, from the intrusive crests (diabase) of Las Juntas, to the north, up to the extensive opening of Hilario, to the south (Km 128 and Km 149, San Juan–Calingasta road, respectively).

This wide belt is made up of a series of heterogeneous materials in which are noted principally the lutite levels, appearing alternately with clay-schist sericitic sandstone, quartzitic sandstones, slatic clays and true graywackes.

The intense tectonic activity in this area, which folded and no doubt repeated much of this sedimentary pile, makes it impossible authoritatively to talk of its thickness. However, we can note that the outcropping exceeds 5 km in width.

Although it is impossible to establish distinctions regarding the ages of sedimentary cycles, zones have been defined in accordance with their main characteristics. These differentiations, the contacts of which are not clear, may possibly be related to the variations in the facies of a Cambrian-Ordovician sea.

From east to west, these zones are found as follows (Fig. 2): a purple-reddish area (clay schists and lutites); a gray-greenish area (lutites, slates and quartzites), and a dark-violet area (alternance of sandstones and lutites).

The first of these is represented mainly by clay schists of a sericitic appearance, which alternate with thin layers of sandstones and conglomerate sandstones with an abundance of iron oxides. Its over-all color is red-purplish with a few dark-green streaks. This zone suffers intrusion from a number of veins, comprised of diabase layers.

The area of profile of Fig. 2 (Km 132 fault) has a width of 800 m and several layers of gray and black lutites which are well mineralized, are intercalated and are the object of a surface operation. One of these layers, located at the base of the whole, has a width of 110 m.

This group is characterized by the marked schist content of its components and by the abundance of tight microfolds, which indicate intense trituration of the same. Variation of color in the lutite is due to the presence of those factors which indicate the existence of unmodified (black) levels and others which have undergone greater alteration (gray).

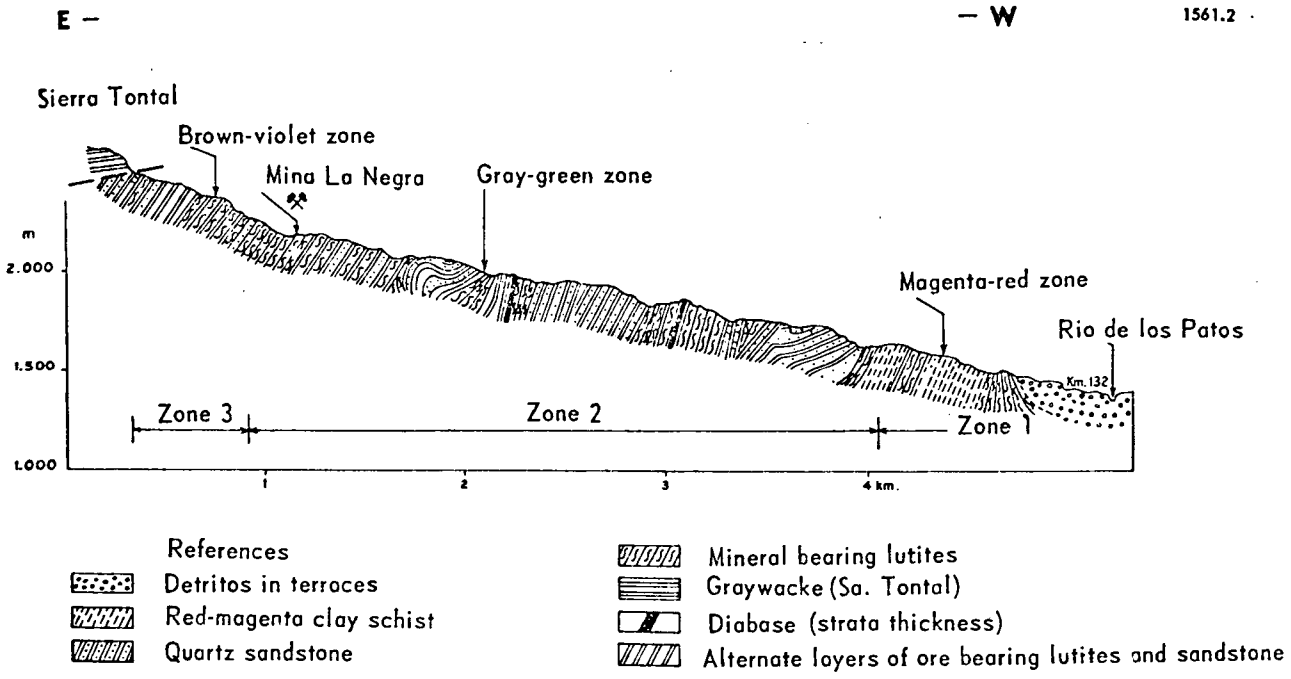

Figure 2. Profile through Km 132 fault, Calingasta

The general orientation of this configuration is N 20° W with variable dips to the east.

The second zone, which is distinguished from the above by its greenish-gray color, is represented by slates, quartzites and sandstones, alternated with many levels of lutites, which carry abundant mineralization. Through this strip of about 3 km width a lower sector with a lighter color is noted, in which substantial amounts of chloritic slates predominate, as well as quartzitic sandstones intruded with diabase veins.

In the upper sector, which is dark in color, a great development of the lutite horizon is found which alternates with layers of sandstones and which constitutes one of the most mineralized strips of the profile.

The third zone is characterized by a regular alternation of sandstones and conglomeradic quartz-containing sandstones, with bunches of lutites, which are also mineralized. The third zone's dark violet coloration shows a typical striped aspect, the origin of which is in the contrast of mixed colors of the sandstones with iron oxidations, and the grayish color of the lutite layers. This circumstance is favored by differences in hardness, indicating successive shoulders in the folding slope. Mineralization of this area is markedly less than in the two preceding zones, and there appears to be a predominance of aluminum sulfates over those of magnesium.

The degree of disturbance of these sediments is less than that revealed by the above groups, and its slope varies between 50° and 60° E. In the profile zone, this strip has a width of 600 m.

Upon these sediments and through tectonic contact, thick banks of nearly horizontal graywackes are found, which would correspond to the lower level of the "group of graywackes of the Tontal sierra" and which determine the eastern limit of the area containing mineralized lutites.

Other areas of schists which contain alum corresponding to the zone of Calingasta are located on the eastern bank of Km 114 fault. This fault, which descends with an approximate N–S orientation into the north fold of the Tontal sierra, opens up in the fault of rio San Juan, in the vicinity of Km 114 along the San Juan-Calingasta highway.

Through these areas, and in the same geological medium, are found the metasediments described in the profile of the Km 132 fault; carrying, in this case, the lutite levels with sulfatiferous impregnations, over 5 km long and about 3 km wide. These areas show a much less disturbed arrangement and maintain their general orientation with variable undulations of 45° and 70° E.

The upper levels described above (Calingasta), a dark-violet area, with alternations of sandstones and lutites, are not represented in this sector, passing directly from the mineralized lutites to the banks of graywackes of the Tontal sierra. The lutitic sediments occupy the high lip of a fault which created the basin that fills the course of the valley.

Those sediments which contain minerals in this area are on the whole similar to those referred to in the Calingasta area and would correspond to two tectonic disturbances separated by Triassic continental deposits.

Rodeo

The area of the alum-containing schists is located in the department of Iglesia, on the western border of the Pre-Cordillera, between the districts of Rodeo and Las Flores, including the fold of Cerro Alumbre and its southern extension, as far as Loma Blanca.

These sediments outcrop for about 13 km to the north and south of the deep valley dug by the Jachal river as it enters the Sierra Negra.

The geological medium in this area begins with the Tertiary sediments which emerge from the terraces and Quaternary pebbles of the Iglesia valley. The reddish and yellowish sandstones ascribed to the Calchaquense (Middle-Upper Tertiary) include an asymmetrical, sinclinal fold, the eastern side of which is broken by considerable diabase intrusions.

In contact with these intrusions is the horizon of lutites and sandstones containing sulfates, limited to the east by large graywacke outcroppings, with slates and quartzites which form the Sierra Negra.

At the opening of the Cuesta del Viento, 40 km from the Jachal-Rodeo highway, two lots of lutites are found, completely integrated by the diabase intrusion, with thicknesses of 30 and 15 m each, 200 m apart.

These sediments, which begin south of the Jachal river, continue to the north for 3 km over the fold of Cerro Alumbre; they are disturbed folded and maintain a fairly even route (N 10° W) with dips of 70° and 80° E.

In the outcropping areas to the north of the river a short profile was made which demonstrates the existence of the two remnants of well-mineralized lutites, one at the lower level with a thickness of 70 m, the other at the upper level with a thickness of 20 m (Fig. 3).

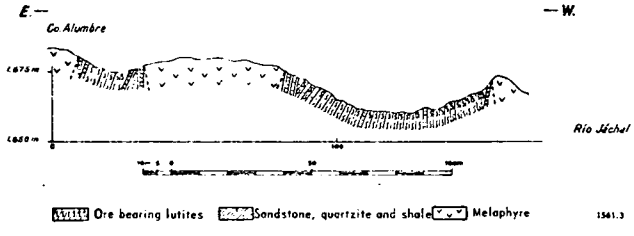

Figure 3. Profile to the north of the Rio Jachal, Rodeo

In the southern area is found an even alternation of sandstones and sulfate-containing lutites which reach a width of 250 m. The characteristics of these sediments, as well as the disposition of the sulfates and the radioactive readings, are similar to those already described, for example those of the Calingasta zone.

Both the alum-containing schists of Calingasta, in which fossil remnants of graptolites are found, and those of Rodeo belong to the Caradocian.

Zone North of Jachal

In the northern region of the Jachal department, the lutitic sediments have a wide diffusion, beginning in the Panacán area to the south and going north ending at the province of La Rioja, near the Guandacol river.

The extensive plain of Panacán is the western limit of the marine sediments of the Eopaleozoic which, arranged in vast strips oriented NW–SE, are repeated up to the eastern fold of the Sierra de la Batea.

Within the Ordovician sedimentation two horizons are recognized which contain lutites; the first in the lower position ("Gualcamayo formation") is represented almost exclusively by dark-colored lutitic levels with scant intercalations of sandstones and yellowish sandstone clay. The schist-containing levels mentioned are arranged in lots several hundreds of meters thick, greatly disturbed by numerous intricate faults, which reveal the action of very intense diastrophic effects.

Along the Los Piojos river, in the Los Celestitos zone, a marked development of this level is found; it reaches a width of 1500 m and a length of about 12 km. The general orientation of this strip is N 30° W with strong variable undulations to the west.

Fossilized remains of graptolites are found, belonging to the Llanvirnian.[2]

The second horizon, which occupies the upper position ("Trapiche Formation") is arranged in concordance on thick banks of Ordovician caliche, which are almost coeval. This formation, which has an ample diffusion zone, consists mainly of sandstones, lutites and conglomerates, which carry a fauna of trilobites and graptolites, referred to the Caradocian. This sedimentary group outcrops in two broad strips which are repeated tectonically, or runs over permocarboniferous horizons. The first of these, the eastern strip, begins south of the Vallecito river, at Puesto El Salto, and continues to the Guandocol river to the north, over a length of about 30 km and a width of over 1 km. Inside these strips the lutite levels are well characterized, blackish in color and have an approximate thickness of 500 m. The western strip of the "Trapiche Formation" is arranged north and south of the plain of Panacán, with a length of several tens of kilometers and an approximate width of 4 km. The outcropping south of this plain forms the base of the permocarboniferous terrains which borders the Panacán river, in the vicinity of which the lutite levels are 400 m wide.

The lutites of the lower group ("Gualcamayo Formation") have an outcropping width of 1500 m; those lutites of the upper level ("Trapiche Formation") include two similar horizons, possibly repeated tectonically, of 500 m and 400 m each.

THE URANIFEROUS LUTITES

These consist of a silica-clay-carboniferous sediment, with a varying proportion of these three elements, of an intense black color, dull to shiny, when fresh which, owing to meteorization, changes to dark and even a light-gray, in the case of the alum-containing schists of Calingasta and Rodeo.

Generally speaking, the structure is compact, with fine stratification, and is well marked, showing a schist content in some cases. The lutites of the zone north of Jachal are, by contrast, of a coarser and less well-defined stratification.

The lots of these sediments reveal no homogeneous composition, and in this respect it is noted that there are frequent alternations of very enriched clay lutites, which are soft to the touch; others are rough, due to their greater content of sandy material; some are even enclosed with small heads of quartzitic sandstones.

Table 1. Chemical Analysis [a]

Constituent	Per cent 1	2	3
SiO_2	62.50	64.00	73.95
Al_2O_3	13.50	12.00	9.89
Fe_2O_3	4.15	7.52	3.36
CaO	2.76	0.92	1.73
MgO	0.33	0.75	1.08
Na_2O	2.11	1.54	2.02
K_2O	2.02	1.93	2.63
TiO_2	0.68	0.55	0.36
V_2O_5	0.10	0.05	0.02
P_2O_5	0.01	0.01	Trace
Moisture at 110°C	1.60	6.06	0.88
H_2O of constitution and organic materials	5.80	10.75	4.02
S	1.78	4.76	2.10

[a] 1. Alum-containing schists, Km 130, Calingasta.
2. Alum-containing schists, "La Negra" mine, Km 132, Calingasta.
3. Lutite, Vallecito river, Puesto El Salto, zone north of Jachal.

Among the minerals which accompany these sediments the following are mentioned, particularly for the areas of Calingasta and Rodeo: alum containing ($Al_2(SO_4)_3 \cdot 16H_2O$) and epsomite ($MgSO_4 \cdot 7H_2O$) in the semi-dehydrated condition; pickeringite or magnesium alum ($Al_2(SO_4)_3 \cdot MgSO_4 \cdot 22H_2O$); jarosite, the product of alteration of pyrite; nickel sulfate (morenosite), which is rare; gypsum; "limonite" and hematite; these last two coloring the lutites to a variable extent.

The above-mentioned minerals could have originated by alteration processes of the alum-containing schists in a very dry climate, such as that prevailing in the areas mentioned. They appear in the form of irregular outcrops, or as a filler of cracks or cavities of varying dimensions, or, finally, as a material which cements ruptured schists.

The most frequent phenomenon in the lutites of the Jachal area is outcroppings of sulfates, weak and isolated, rarely with small concentrations of high purity.

Microscopic observation carried out by Doctor Jorge Villar Fabre, Chief of the Laboratory Division of Geological Investigations of the National Commission of Atomic Energy, makes it possible to distinguish a quantitative rather than qualitative variation in the composition of the various samples investigated.

The siltic and clay fractions are not constant, but one or the other predominates according to the area from which the sample has been taken. In all of them, the high proportion of organic matter, jointly with hematite, complicates microscopic observation by concealing the other elements.

These compounds extend throughout the sample, leaving in some cases clear spots occupied by clay minerals. The latter are made up of illite, chlorite and sericite. The sericite is sometimes abundant and its scales are oriented in parallel.

Quartz is represented by anhedral grains the dimension of which rarely reaches 112 μ; it is generally between 40 and 20 μ, being very rare in some samples, whereas in others it is the predominant mineral (lutites of the zone north of Jachal).

Plagioclase is extremely scarce, anhedral and comparable in size to quartz.

On some cross-sections the presence of carbonate (dolomite) is noted; this covers uneven areas of up to 0.16 mm in diameter or in small grains scattered through the rock.

Pyrite is a component, the proportion of which varies according to the source of the samples; it is found in rounded aggregates of irregular form approximately 90 μ in diameter and in crystals having square contours of 0.10 mm in diameter.

Zircon grains without particular characteristics are seen and, in only one spot, a mineral similar to carnotite, the scarcity of which did not permit its isolation for accurate determination.

In order to ascertain the chemical composition of these sediments, the analyses reported in Table 1 were carried out.

These analyses show the variable composition, as a logical consequence of the varying proportion of sandy, clayey and organic materials contained in these sediments. There was practically no phosphorus and the sulfur content corresponds to iron sulfide and soluble sulfates which impregnate them.

The semi-quantitative spectrographic analysis of three samples, two from the Calingasta zone and the other from the zone north of Jachal, revealed the following content of minor metals: Cu, 0.01%; Pb, 0.01 to 0.1%; Zn, 0.01%; Ni, 0.01% to 0.1%, and Mo, less than 0.01%.

The uranium content of these lutites was determined by fluorimetry from samples extracted at various points, principally from the Calingasta and Rodeo areas, and efforts were made to obtain the material in as representative a condition as possible, in areas being worked or abandoned. The values obtained are shown in Table 2.

Table 2. Uranium Content of Lutites

Location	U_3O_8 g/ton
Calingasta	
Fault Km 114	30
Fault Alcaparrosa, Km 129	12
Fault Km 130 No. 1	17
Fault Km 130 No. 2	20
Fault Km 130 No. 3	18
Fault Km 130 No. 4	35
Fault Km 130 [a]	25
Fault Km 131	25
Fault Km 132 No. 1	27
Fault Km 132 No. 2	30
Fault Km 132 No. 3	30
Fault Km 135 [a]	63
Rodeo	
South of Rio Jachal—Upper level, dark area	34
South of Rio Jachal—Upper level, dark area	100
South of Rio Jachal—Lower level, gray area	47
North of Rio Jachal—Upper level, dark area	20
North of Rio Jachal—Upper level, gray area	100
North of Rio Jachal—Upper level, gray area	30
North of Rio Jachal—Lower level, gray area	80
Zone North of Jachal	
Panacan River, La Virgencita	25
El Vallecito, Puesto El Salto	30

[a] Sandstones with iron oxidations intercalated between lutite layers.

Summing up, according to the data mentioned, it would seem that the mean content of these sediments is between 20 and 30 g of U_3O_8 per ton. Greater values are recorded in the Rodeo area.

Serial samples belong to various levels. The radioactivity measurements carried out with "scintillometers" along given profiles revealed values no higher than those corresponding, in general, to the spots of the analysed samples, since it is assumed that no layers of a greater uranium content exist.

The uranium contained in these sediments is soluble in acids.

ORIGIN OF THE URANIUM

Considering the wide distribution of the uranium in the sediments and the uniform content in the various lutite layers which make up its complex, the authors maintain that for these elements the origin must be syngenetic.

As regards the origin of the uranium and its form of deposition in the alum-containing schists or lutites as an integral part of its composition, it is felt that the theories advanced—particularly by Swanson,[3] McKelvey, Everhart and Garrels,[4] Goldschmidt [5] and others, would apply to our case.

The uranium was brought in solution, probably to the sea, from the surrounding ground, in proportions which may well have been normal. In these conditions it was absorbed, together with the other accompanying metals, such as vanadium, nickel, copper, etc., in abnormal quantities by the organic matter of the marine mud in which it was deposited; furthermore, the iron sulfide present followed it. At the same time the possibility is not ruled out that the original uranium (hexavalent) would have been reduced to tetravalent, being precipitated by the action of the hydrogen sulfide acid in this reducing medium.

Without major investigation it has not been possible to determine whether the uranium reaches its highest concentration in those lutites which are richest in organic matter, nor whether there is a relationship between the uranium in lutite and that contained in the pyrite.

The deposition conditions of the alum-containing schists of Calingasta and Rodeo and of the lutites of the zone north of Jachal correspond to tropical seas, with background oscillations; however, for the most part they are not very deep, as is clearly shown by the alternation of calcareous rocks, lutites and sandstones and by their fauna content.

REFERENCES

1. V. Angelelli and R. Trelles, *Las alumbreras de Rodeo y Barreal y los sulfatos de hierro de La Alcaparrosa (Prov. de San Juan)*, Estudio minero-geológico, Bol. Obras sanit. nación, Nos. 8, 9 and 10, Buenos Aires (1938).
2. G. Furque, *Hoja 17 b Punilla*, Dir. Nac. Geol. Min., to be published (1957).
3. V. E. Swanson, *Uranium in Marine Black Shales of the United States*, Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Geneva 1955, P/51, Vol. 6, p. 430, United Nations, New York (1956).
4. V. E. McKelvey, D. L. Everhart and R. M. Garrels, *Origin of Uranium Deposits*, Econ. Geol., Fiftieth Ann. Vol. 1905–1955, Part I, pp. 465–553, Lancaster, Penn.
5. V. M. Goldschmidt, *Geochemistry*, p. 566, Oxford (1954).