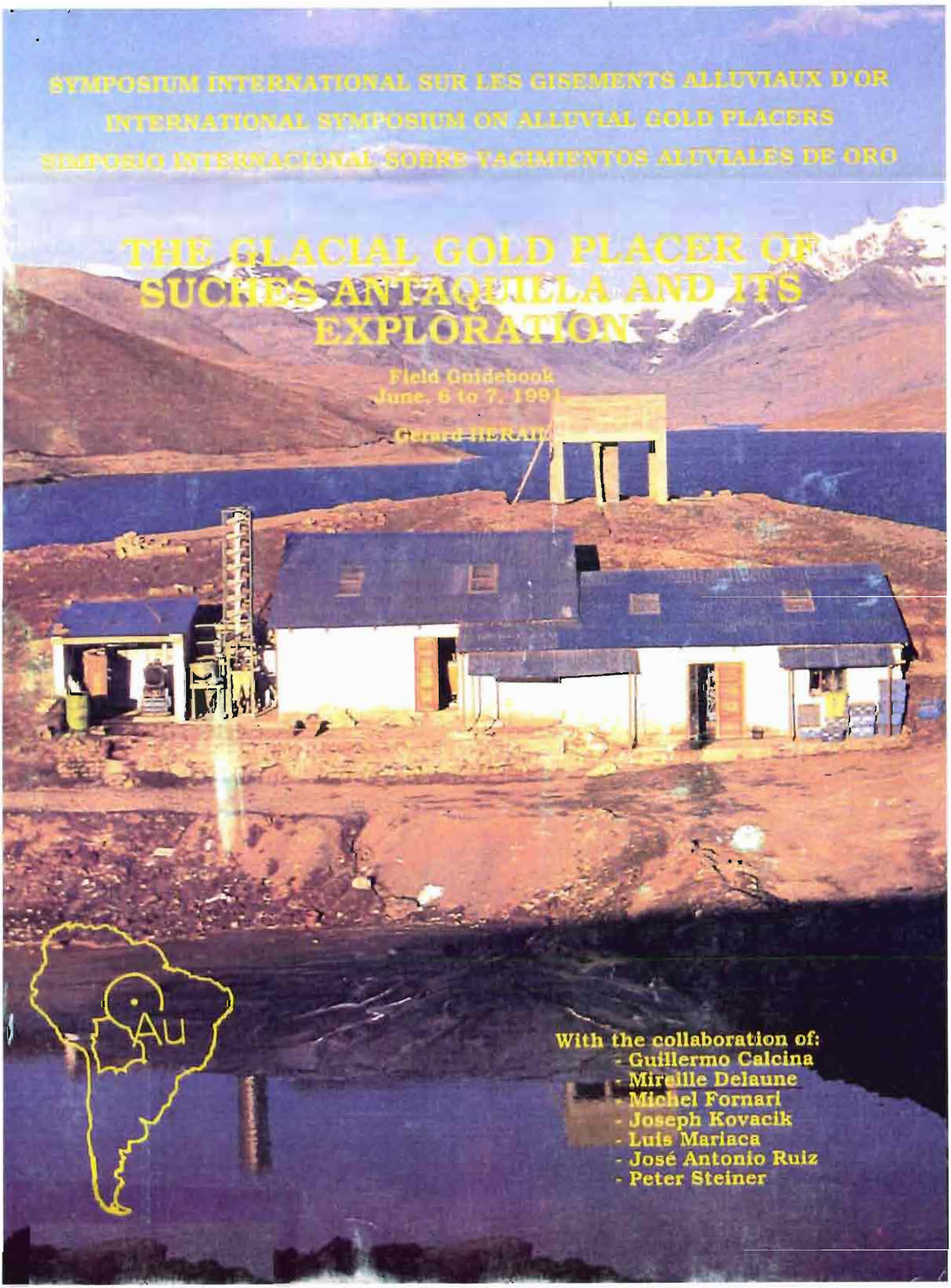

SYMPOSIUM INTERNATIONAL SUR LES GISEMENTS ALLUVIAUX D'OR

INTERNATIONAL SYMPOSIUM ON ALLUVIAL GOLD PLACERS

SIMPOSIO INTERNACIONAL SOBRE YACIMIENTOS ALUVIALES DE ORO

THE GLACIAL GOLD PLACER OF SUCHES ANTAQUILLA AND ITS EXPLORATION

Field Guidebook
June, 6 to 7, 1991

Gérard HERAIL

With the collaboration of:
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The purpose of the field trip to the Suches-Antaquilla area is to show a glacial placer which is being explored and evaluated at the time.

This placer, located at the piedmont of the Apolobamba Cordillera, forms part of a gold mineralized area which extends northwards, into Peru. It belongs to a region of great mining tradition where the exploitation of gold probably started at precolonial times. As early as in 1542, the Spaniards were panning gold around the Suches Lake and there are still many remains from those mining activities and its infrastructure and camp. At the end of last century, an English company exploited the moraines with monitors, producing 11.42 kg of gold in 1899. Later, exploration and evaluation work was done at different degrees by South American Placer Co. (1959), Comibol and Geobol (in the seventies), Estalsa (1986), and other entities. Artisan exploitation of the alluvials has always been maintained in the area, both in Suches as well as in Antaquilla.

The exploration work to be seen during this field trip is done by mutual agreement (Project BOL/88/NO1) between the Bolivian Government and UNRFNRE (United Nations Revolving Fund for Natural Resource Exploration) who signed a cooperation agreement with ORSTOM (Institut Français de Recherche Scientifique pour le Développement en Coopération).

1. THE ITINERARY FROM LA PAZ TO ANTAQUILLA (Fig. 1)

This stretch, 291 km long is covered in approximately 7 hours and runs mainly in high mountains areas (over 3800 m above sea level).

Leaving La Paz towards El Alto and the Altiplano through the valley of the Kaluyo River, starting at the housing development of Autopista, one can see the main terrains which oucrop in the region of La Paz. At this point one observes recent glacial and fluvioglacial deposits of the Choqueyapu glaciers (Dobrovolny 1962, Servant 1977) representing the last glaciation. These deposits rest on the upper most strata of the La Paz Formation. They consist of grey or ochre lacustrine lime-clay sediments interbedded with fluviolacustrine sands and conglomerates. The base of this formation is dated to 5.5 m.a. in Cota Cota (Lavenu et al. 1988). In the upper part remnants of a tuff layer (Chijini tuff) with an age of 2.8 m.a. are found (Lavenu et al. 1988). This tuff appears on the left side of the highway at Ciudad Ferroviaria. A little farther away, in an area planted with Eucalyptus trees, outcrops of ancient morainic deposits in light grey color attributed to the Calvario Glaciation with no precise nor definite age but which is younger than the limit Gauss/Matuyama (2.48 m.a.) and older than the Olduvai Event (1.8 m.a., Thouveny et al. 1989). Continuing, one observes fluvioglacial sediments cut by a normal fault (particularly clear on the left side of the highway) which is characteristic for the tectonic of extension, which structured the La Paz basin during the Pliocene and Quaternary (Lavenu 1986). The ascent continues, cutting beige to ochre color conglomerates (Purapurani Formation) deposited in a fluvioglacial environment. At the highway toll station, on the right side of the highway, appears the top of the Purapurani Formation, covered, in erosive discordance, by till flows of the Sorata Glaciation (the penultimate glaciation of the Cordillera Real). They are covered by recent fluvioglacial deposits, which represent the top of the filling of the La Paz basin.

After having crossed the City of El Alto along the Juan Pablo II Avenue, these same fluvioglacial deposits appear while at the same time the related moraines can be seen to the Northeast (right) descending from the massives of the Cordillera Real (Huayna Potosí 6.060 meters above sea level). About 200 metres before reaching the road toll, one crosses the San Roque River and on the left of the road are outcropping fluvioglacial deposits (ochre) of the Sorata Glaciation overlapped by fluvioglacial deposits (grey) of the Choqueyapu Glaciation. The two formations are separated by a red paleosoil.

The same scenery, characteristic for the Altiplano foot hills of the Cordillera Real, continues all the way to Huarina (km 72) pierced by remnants of the pre-pliocene substratum. For example at km 30 on the right of the highway, one sees reliefs formed in red Terciary conglomerates (Aranjuez Formation) overthrusted by Devonian terrains. Further to the Northwest, starting at km 51, in the area of Chirapaca, on the right side of the highway, one sees sandstones of the Devonian while on the left, on an isolated hill, sandstones, marls and limestones of the Permo-Carboniferous become visible (Copacabana Formation). It is on this hill, close to Yaurichambi, where the in last century Alcides d'Orbigny described a Permo-Carboniferous fauna.

Shorthly after Batallas (km 58), on the right, Lake Titicaca appears. This lake, 180 km long and 69 km wide, covers a surface of 893 km2 and is divided in two lacustrine basins separated by the Straits of Tiquina, which are only 800 metres wide and have an average depth of 40 metres. The basin located in the Southeast forms the "Small Lake" or Huiñaymarca, with an average depth of only 9 metres, and the deepest point reaching 42 metres in depth. It is the shores of the "Small Lake" which we follow until Huarina (km 72). The basin found towards the Northwest, representing 84% of the total surface of Lake Titicaca, forms the "Big Lake" or Lake Chuquito. Its average depth is 135 m, with a maximum of 284 m. From Huarina to Achacachi (km 91), we cross terrains which build up the Straits of Tiquina and farther ahead we follow the shores of the Big Lake, dominated (on our right) by the Illampu, with an altitude of 6,485 m. In

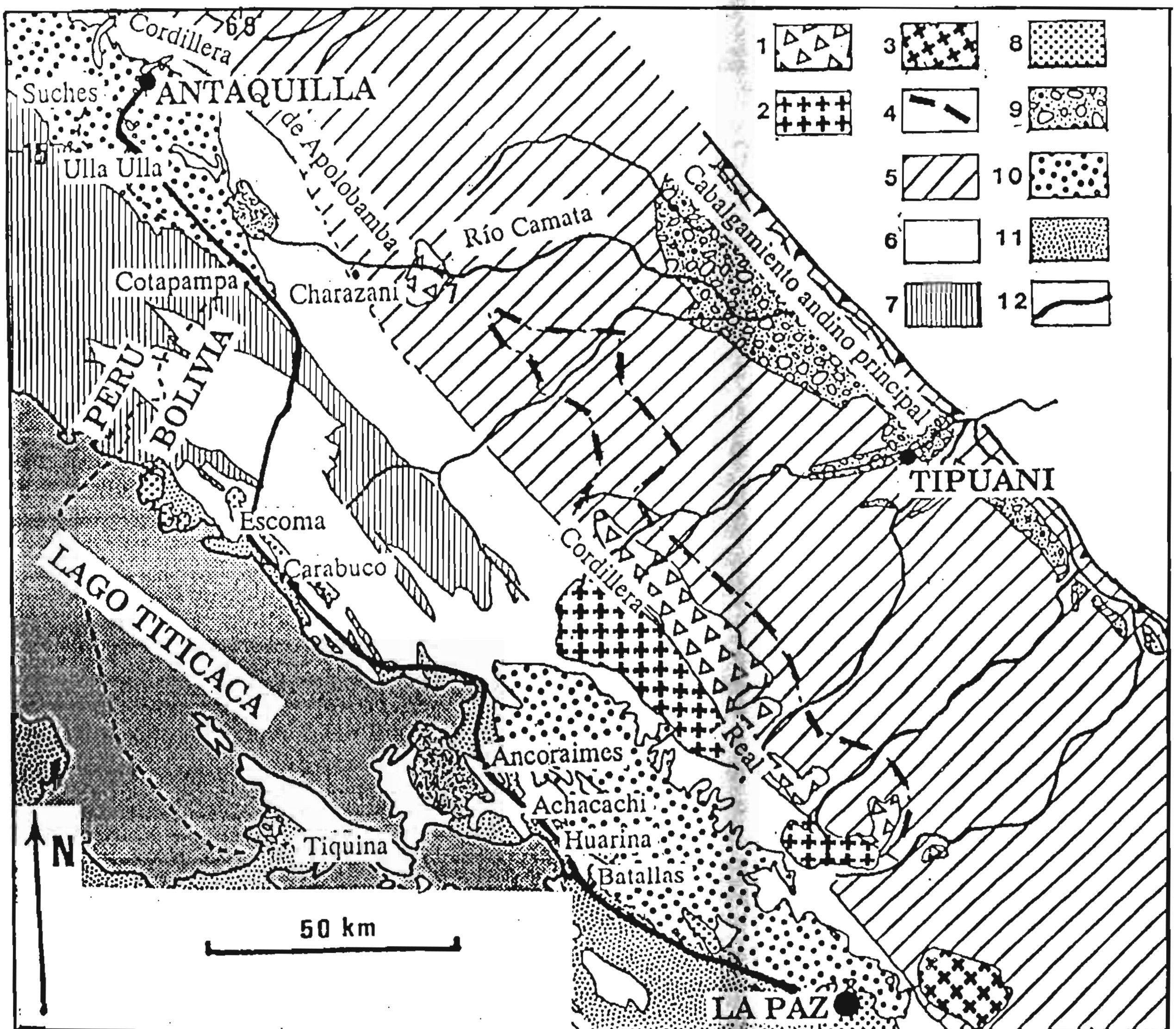

Fig. 1. Simplified geological map of the area located between La Paz and Antaquilla (Compiled from Martinez 1980, Tistl 1985, Hérail et al. 1988, Sempere et al. 1990).

1 - Eohercynian syntectonic orthogranite of Zongo, 2 - Triassic granodiorite of Illampu - Huayna Potosi, 3 - Miocene granite, 4 - High and middle metamorphism zone boundary, 5 -Ordovician, 6 - Silurian to Permian, 7 - Undifferentiated Cenozoic strata, 8 - Oligocene to Pliocene (La Paz Formation, Aranjuez Formation...), 9 - Cangalli Formation, 10 - Glacial and fluvioglacial sediments (Quaternary), 11- Fluvial and lacustrine sediments (Quaternary). 12 - Itinerary of the fieldtrip

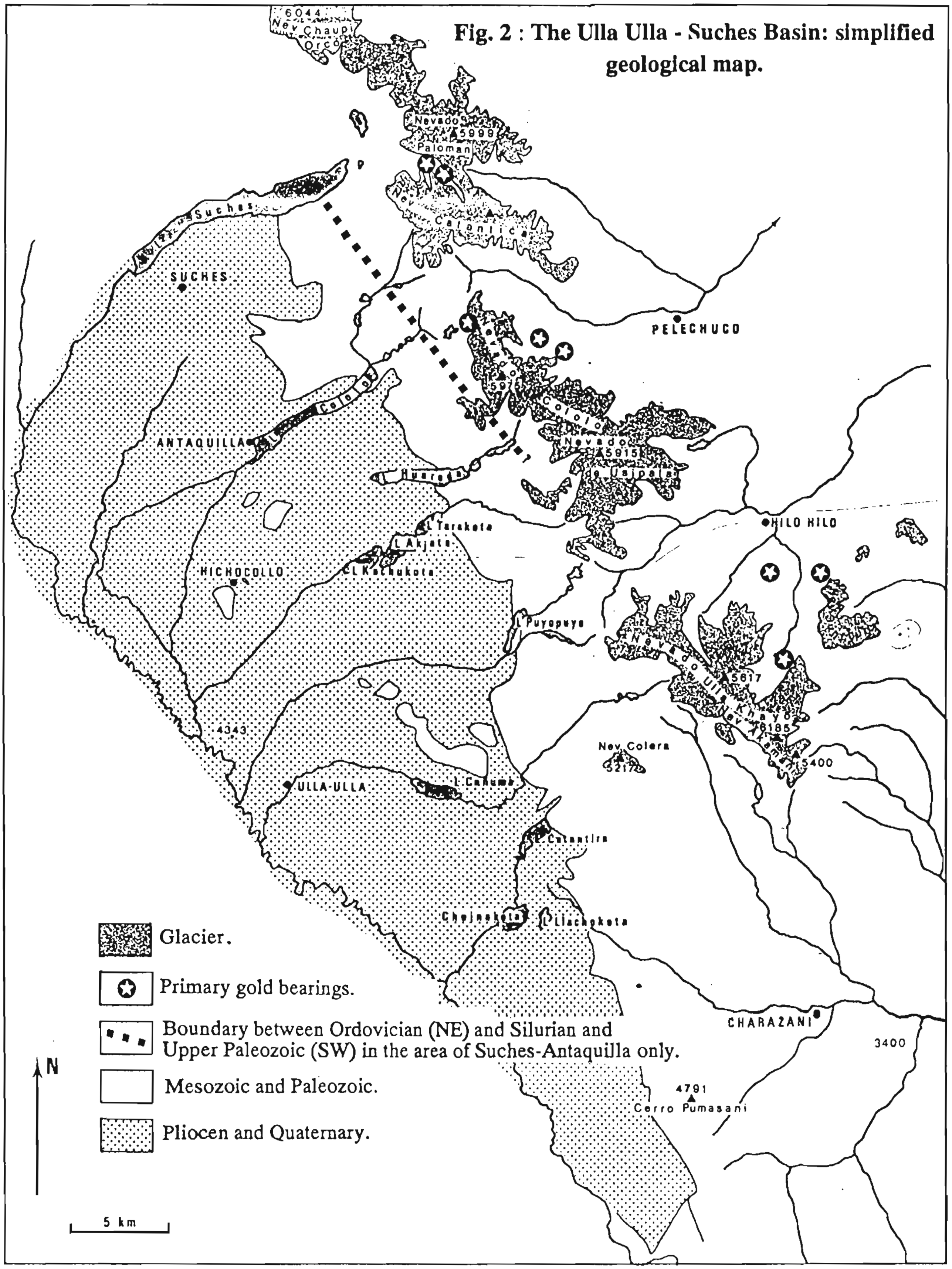

Fig. 2 : The Ulla Ulla - Suches Basin: simplified geological map.

all of this area, passing by Ancoraimes (km 128), Carabuco (km 153) until Escoma (km 167), we cross Devonian formations. On the left, along the shore, repeatedly outcrop Terciary intrusives and red Cenozoic sediments. Close to Escoma (km 162), we find thick outcrops of banked red sandstone of the Mesozoic. The fine stratified silty-sandy alluvial sediments found in the lower parts of the road correspond to lacustrine deposits of the Paleolake Titicaca, when the water level was higher, an event, which happened a number of times during the Quaternary (Servant et al. 1978).

From Escoma (km 167), the road heads towards the North and crosses an area of a very complex tectonic structure (the "Fold and Thrust Belt of Huarina", Sempere et al. 1990), characterized by outcrops of Devonian, Carboniferous, Permian and Cretaceous sediments (Rivas 1968), with the probable but not proved existence of Juriassic rocks (Barrios 1989). The morphology of this area is characterized by an important dissection (valleys of the Suches river and its tributaries towards the West and valleys of the headwaters of the Consata river towards the Northeast), the presence of karstical forms in limestones of the Copacabana Formation (Permian), and the large extension of glacial deposits.

From the crossroad of the Charazani highway (km 235), the relief becomes smoother and deposits of glacial origin cover the major part of the terrain. Shortly after the village of Cotapampa (km 241), one arrives at the Chojñakota Lake (on the right of the road, km 253), the most meridional of the big lakes of the Suches-Antaquilla-Ulla Ulla pampa (Fig. 3).

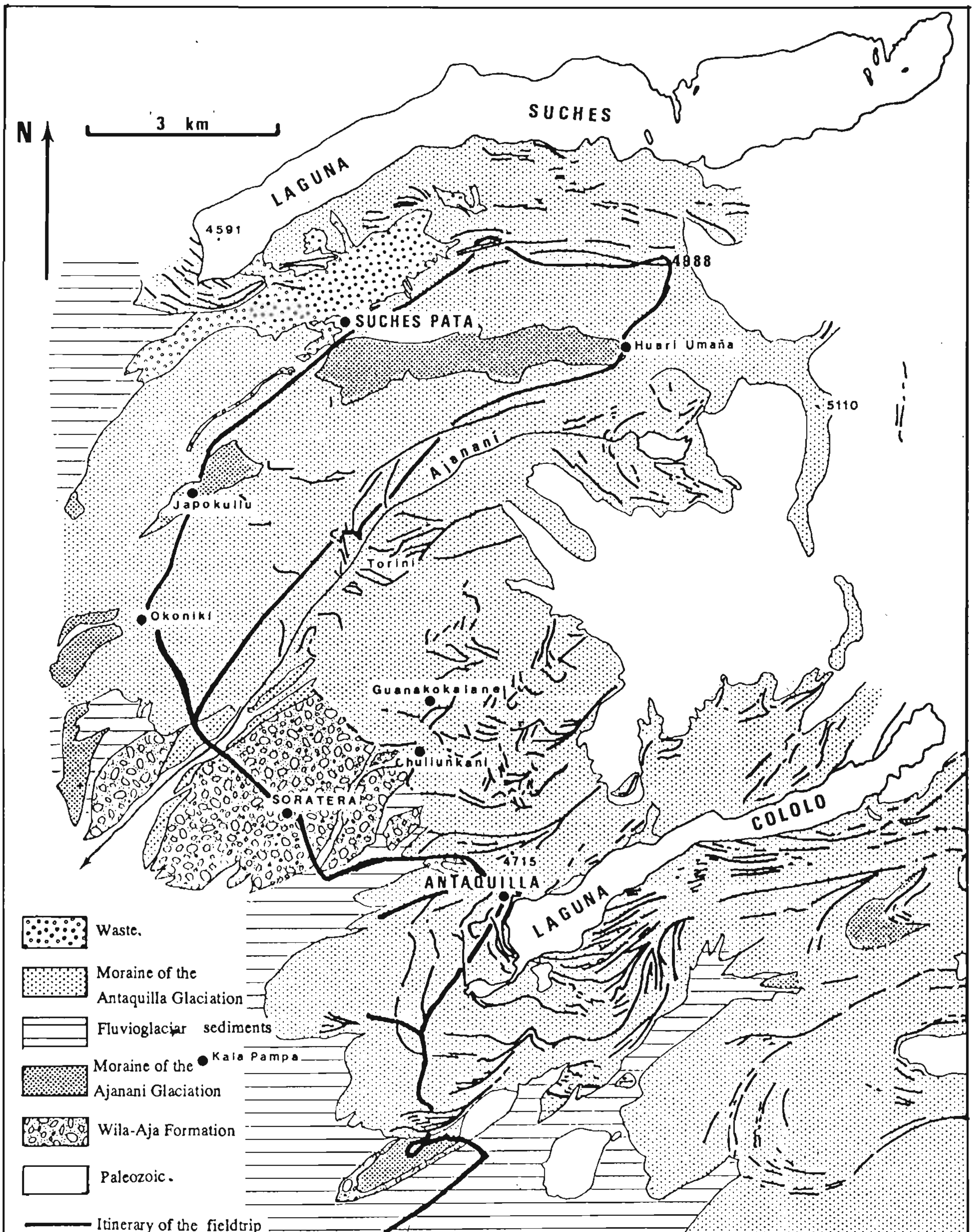

Fig. 3: Simplified geological map of the Suches-Antaquilla basin (after Hérail and Ruiz 1990)

2. THE PROGRAM.

The visit of the Suches-Ulla Ulla prospect includes:

- the ore deposits presentation according to the itinerary shown at fig. 3. The zone near the camp of Antaquilla will be visited the 6th of june in the afternoon. The following day (7th june), in the morning the northern part of the region will be seen.

- it will be presented also the sampling and the processing of the samples in the pilot plant of Antaquilla.

- during the visit some mineralisation characteristics will be described.

3. GEOLOGY OF THE ALUVIAL DEPOSITS EXPLORED FOR GOLD IN THE SUCHES-ANTAQUILLA BASIN.

The Ulla Ulla basin (69° 15' West) has a width of about 10 to 12 km and it extends for over 60 km in length between 14° 45' and 15° 15' of latitude south (See figures 2 and 3).

The altitude varies from 4300 and 4800 m.a.s.l.. This is the southernmost basin of a group of intermontane basins that are bordered by the Cordillera Oriental, from Macusani passing by Crucero and Ananea (See Figure 2).

The sedimentary filling of these basins is complex; if we make an exception for the Crucero basin, in which the filling begins with detritic sediments probably of Oligocene age (Laubacher et al. 1988), the sedimentary pile which lies over the paleozoic basement is formed, from base to top, by palustrine deposit of Pliocene age, interbedded locally with volcanites and overlayed by a succession of fluviatil deposits and fluvioglacial and glacial deposits (Fornari et al. 1980, 1981, 1982, Bonnemaison et al. 1983, Lauer y Radiqpoor 1986, Gouze 1987, Hérail et al. 1989). But the accumulations of glacial and fluvioglacial sediments are the ones that control the geomorphology of these basins.

In the northwestern border, at the foot of the Cordillera, the morphology is characterized by the superposition of several frontal and lateral hills forming moraines, while towards the southwest they extend in plains slightly tilted due to fluvioglacial spills and fluvial post-glacial sediments around the main rivers (Suches, Antaquilla...). These plains reach to the foot of the Precordillera of Carabaya and its prolongations that border these basins towards the southwest and that separate them from the Altiplano.

1) The Ulla Ulla-Suches basin: stratigraphy of the Cenozoic fillings.

The Cenozoic sedimentary series that fill the northeastern part of the Ulla Ulla basin rest over paleozoic terrains (fig. 3). Devonian or Silurian shales and sandstones are placed at the NE margin of the basin, while towards the WSW only a few "islands" of upper Paleozoic terrain outcrop, in which the Copacabana Formation is well represented (Perez 1976).

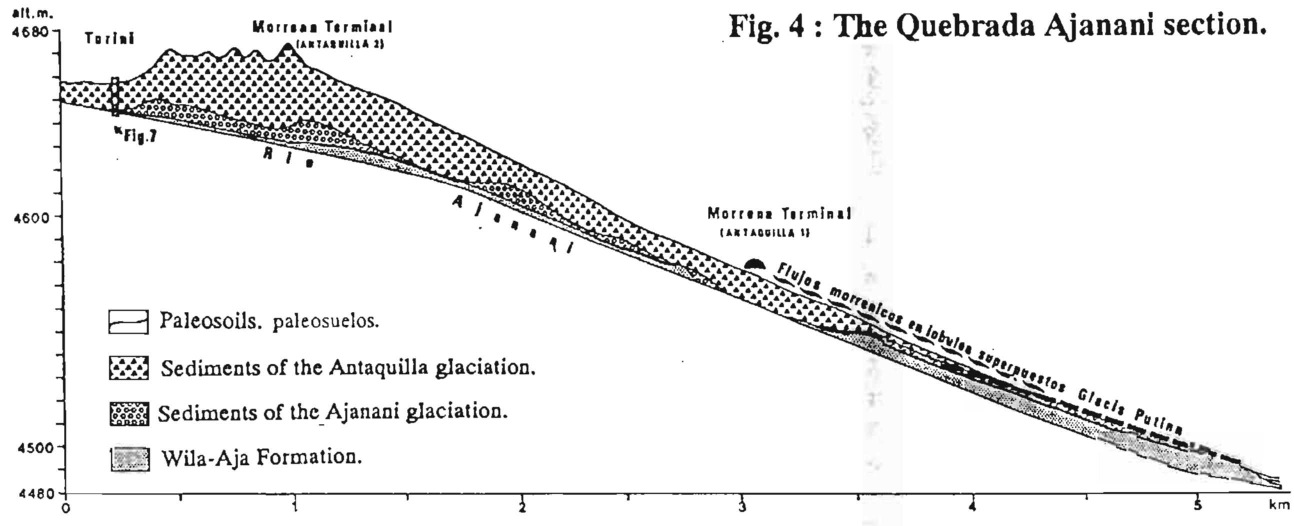

Fig. 4 : The Quebrada Ajanani section.

In the area of the Ajanani creek (fig. 4) the superposition of the main stratigraphic components is observed. At the bottom, conglomerates with well rounded cobbles are outcropping and are denominated as WILA-AJA FORMATION, at the top these conglomerates are cut by an erosion surface, caused by the Soratera pediment, in which a thick red soil was developed, and partially preserved. This ensemble is covered by a thin bed (1 to 3 m) of ochre coloured morainic sediments, these are remnants of a glacial event that we call the AJANANI GLACIATION. Locally, these sediments are cut by the PUTINA PEDIMENT. A complex accumulation of grey to beige colored sediments, that we attribute to a glacial episode that we call the ANTAQUILLA GLACIATION, rests over the sediments described above. These sediments are generally on erosional contact over the former sediments and only in a few exceptions a paleosoil, developed over the moraine of the Ajanani Glaciation, has been preserved. The sediments attributed to the Antaquilla Glaciation cover all the terrain formerly described and conform the greater part of the outcrop; its thickness can reach up to 40 metres. Downstream the facies changes from glacial into fluvioglacial.

On a regional scale, stratigraphic correlations can be established directly with the neighbouring Ancocala-Ananea basin located in Peru, just on the other side of the frontier.

CUENCA DE ANCOCALA-ANANEA (Peru)	CUENCA DE ULLA ULLA-SUCHES (Bolivia)	CUENCA DE LA PAZ, PIEDEMONTE DE LA CORDILLERA REAL (Bolivia)	EDAD
Glaciación Islapampa	Glaciación Antaquilla II	Glaciación Choqueyapu II	27000 BP
Glaciación Chaquiminas	Glaciación Antaquilla I	Glaciación Choqueyapu I	
Glacis gl T4	Glacis Putina	Glacis IV	
Glaciación Ancocala	Glaciación Ajanani	Glaciación Sorata	
Glacis gl-T5	Glacis Soratera	Glacis III	
Glaciación Limata	Formación Wila-Aja	Formación Purapurani: Glaciación Kaluyo	
Formación Arco-Aja		Formación Purapurani	
		Formación Purapurani: Glaciación Calvario	
		Formación La Paz: ▲ ▲ ▲Toba Chijini	2,8 m a
▲ ▲ ▲Toba Arco Ajja			3,8 m a
		Formación La Paz: ▲ ▲ ▲Toba Cota-Cota	5,3 m a

Table 1: Stratigraphic correlation between Plio-Quaternary formations of Ancocala-Ananea, Ulla Ulla-Suches and La Paz basins.

The Wila-Aja Formation can be related to the Arco-Aja Formation on which a tuff horizon was dated at 3,8 m.y (Laubacher et al. 1984). The Soratera pediment and the red paleosoil can be traced to the Ancocala region in Peru, where it was designated as pediment gl-T5. In this basin, the gl-T5 is covered by the Ancocala glacial sediments (Fornari et al. 1982, Bonnemaison et al. 1985, Hérail et al. 1989); that is the basis to admit that the Ancocala Glaciation and the Ajanani Glaciation correspond to the same glacial event. The Putina pediment, that cuts the Ajanani glacial morphology and sediments, carries a less developed soil than the Soratera pediment, and is contemporaneous to the pediment gl-T4 of the Ancocala-Ananea basin. The most recent sediments and the Antaquilla glacial morphology are contemporaneous to the event that in Ananea was designated as Chaquiminas Glaciation (Hérail et al. 1989).

The different formations that are present in the Ulla Ulla-Suches basin, as well as in the Ancocala-Ananea basin, are represented or have its equivalents in the La Paz basin and are located over the southwestern piedmont of the Apolobamba Cordillera. The La Paz Formation (Dobrovolny 1962) near its base contains a tuff horizon (Cota Cota Tuff) dated at 5,3 m.y (Lavenu et al. 1989) and near its top the Chijini tuff was dated at 2,8 m.y. (Lavenu et al. 1989, Thouveny et al. 1989), thus the Arco-Aja and Wila-Aja Formations are, at least in part, contemporaneous to the La Paz Formation. Nevertheless, in the Ulla Ulla-Suches basin we have not observed clear episodes of older glaciations (i.e. Calvario and Caluyo) neither remnants of the Purapurani Formation described in the La Paz basin (Dobrovolny 1962, Servant 1977, Lavenu 1986). All the formations and the most recent geomorphology described for the Ancocala-Ananea as well as the Ulla Ulla-Suches basins, are represented also in the La Paz basin and in the Real Cordillera piedmont. The Ajanani Glaciation is contemporaneous to the Sorata Glaciation and the two main facies of the Antaquilla Glaciation belong to the Choqueyapu I and Choqueyapu II facies of the latest glaciation, described in the surroundings of the city of La Paz (Servant 1977, Argollo 1982). The moraines corresponding to the Choqueyapu I facies could not be dated; they are older than the ages that could be obtained by Carbon 14. The moraines that correspond to the Choqueyapu II facies rest over sediments that could be dated to at least 27.000 years BP (Servant et al. 1978). In the Vilcanota Cordillera (southern Peru) it was established (Mercer et al. 1977) that this glacial facies would be between 28.560 y.BP and 14.010 y.BP.

2) The different stratigraphic and geomorphological units.

2.1) The Soratera pediment and Wila-Aja Formation.

The Wila-Aja Formation (fig. 5) corresponds to a conglomerate formed by well rounded cobbles, generally well imbricated, but where volumewise the matrix is important. In this conglomerate the boulders over 30 cm in diameter are rare. We have not encountered striation in the cobbles.

The Wila-Aja Formation has an homogeneous structure; 10 individuated channels appear to be present and generally the granulometric gradient between the bottom and the top of a sequence is weak. The sandy components are rare and there are no clay-silty strata. Thus each sequence appears as the deposition product of a non-channeled flux, as weakly winding braids, that drains over an unaccidented topography and slightly tilted towards the south.

On the top, the Wila-Aja Formation is cut by an erosional pediment (Soratera pediment) slightly inclined from the ENE towards the SSW. On its surface, a complex weathering profile is preserved (fig. 5F) which is composed by the superimposition of a layer (0.5 to 1.2 m thick) of grey to very clear ochre conglomerates with a vacuolar sandy matrix and an inferior red layer (3 to 3.5 m thick), with a matrix rich in clay. In the upper light colored horizon discontinuous red clay cutanes still appear on the pebbles. The contact between this horizon and the inferior red horizon is clear but it is done through tongues of vertical development of 20 to 30 cm in lenght which put in interdigitation the grey to ochre horizon overresting and the red underresting, nevertheless, there is no sedimentary discontinuity between these two horizons. In the red horizon, the rubefaction and argillization are strongly marked to a depth of 4 to 4.5 metres and deeper down they gradually become less intense, with the appearance of a transition zone of about 1.5 m thick. Afterwards, between 6 and 6.5 m depth, the sediments are not weathered. So the surface that appears in the Soratera region corresponds to an erosion pediment cutting Wila-

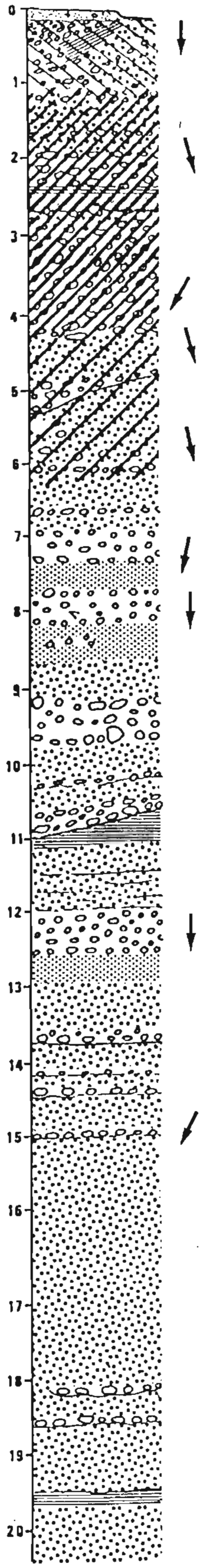

Fig. 5 : The Wila-Aja Formation.

(The arrows indicate the flow direction)

1 Grey paleosoil of degradation.

2 Clayed red paleosoil.

3 Transition zone between the paleosoil and the not weathered sediment.

4 Sands covering the Putina pediment.

5 Clay.

6 Sand.

7 Gravels.

8 Pebbles and gravels.

9 Boulders and pebbles.

Aja F. and the weathering profile which covers it constitutes a good level guide but only remains well conserved in places where it has not been eroded and/or covered with younger glacial or fluvioglacial sediments.

Upstream from the Cololo lake, close to the village of Altarani, an outcrop of small extension located on the edge of the basin shows that towards the bedrock this formation becomes finer, the conglomerates overlie silty clay loam, the same which overlie directly the paleozoic substratum. The fine sediments of the lower part of this outcrop are only about ten metres thick.

2.2) The sediments of the Ajanani Glaciation and the Putina Pediment

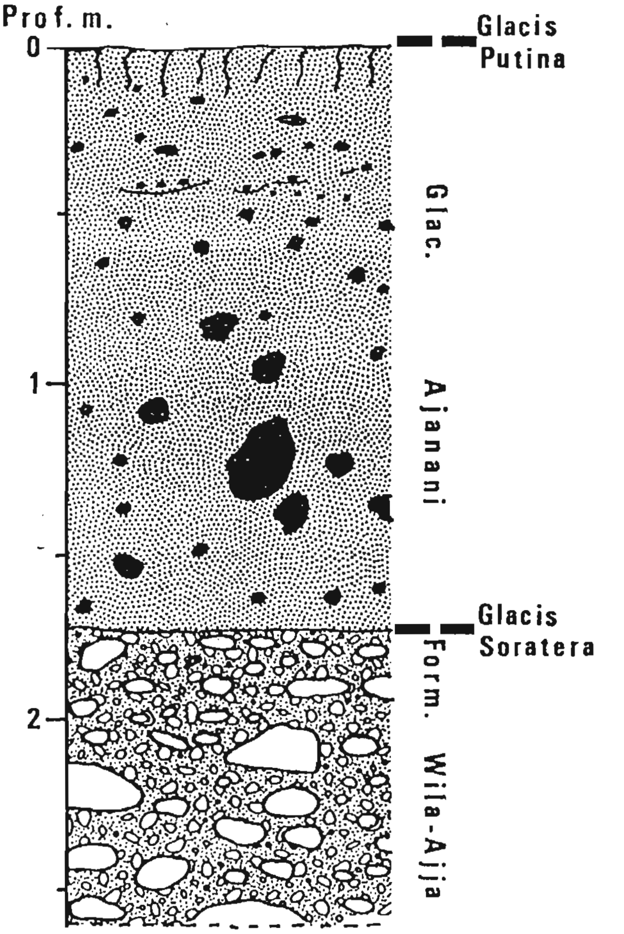

Fig. 6: Superposition of the Ajanani Glaciation and of the Wila-Aja Formation sediments between the Sorapata river and the Putina river.

Generally, the Wila-Aja F., as well as the Soratera pediment, have been eroded and covered by morainic sediments of ochre color, vestiges of a glacial episode called Ajanani Glaciation (fig. 4). Such sediments outcrop at the section on both sides of the Ajanani River valley and most of all on the plains of Japokollu and Chijipampa and in the valley of Japutira River. Nevertheless, they never conform morainic arches or lateral moraines. The morainic sediments of the Ajanani Glaciation overlie the Wila-Aja F. and the Soratera pediment in erosional discordance. Generally, the paleosoil that covers the Soratera pediment is partially conserved which means that the volume eroded during the progression of the glaciers of the Ajanani Glaciation was inferior to the volume of the paleosoil developed on the Soratera pediment at least downstream from the valleys where outcrops exist.

When the sediments of the Ajanani Glaciation appear on the surface, there are cut by a surface of erosion, the Putina pediment (fig. 6) and map out of text).

2.3) Forms and sediments of the Antaquilla Glaciation

In many cases, the correlative sediments of the Ajanani Glaciation, as well as the oldest terrains, are covered by a grey to ochre glacial and fluvioglacial deposits, with variable thickness but it may reach about 60 metres, which we attribute to the Antaquilla Glaciation. Between the villages of Suches and Soratera and the foot of the Cordillera, observation and mapping of the contact between the sediments attributed to the Ajanani Glaciation and the sediments attributed to the Antaquilla Glaciation show that the contact surface is not flat and corresponds to wide valleys reworked by fluvial erosion and in some cases paleosoils remains are conserved (fig. 4) in their contact.

2.3.1) Extension of the different glaciers contemporaneous of the Antaquilla Glaciation

The geomorphological mapping and sedimentary analysis have made possible the individualization, between the Suches lake and the Cololo lake, of four main paleoglaciers:

- The Antaquilla Glacier which was being fed by snow developed in the Catantica (5,975 m) and Cololo (5,915) massifs. Its development was of about 19 km long and it left downstream a system of lateral moraines with an extension, on the left side of the Cololo lake, of approximately 7 km long and 1.5 km wide with a maximum thickness of about 300 metres, while, along the right side of the lake, the moraine deposits left by the glacier are much more discontinuous. A complicated morainic system closes the Cololo lake downstream, composed at the same time by frontal moraine deposits, overglacial moraines and ground moraines. This system reaches almost 4 km in width and almost 4 km of longitudinal development. It is difficult to determine its thickness but it does not seem to be over 100 metres. In its major extension, the glacier face was found at 4,450 to 4,460 m above sea level.

- On the northeast side of the concession, the Suches Glacier was fed by snows found in the Catantica (5,975 m), Mount Palomani, (5,999 m) and Chaupi Orco (6,044 m) massifs. It consisted of a tongue whose longitudinal development also reached about 20 km. On the left side of the Suches lake, on the Bolivian side, the glacier left a series of lateral moraines of about 6 km long, 3 km wide and approximately 250 m of maximum thickness. Only frontal moraines of reduced extensions remain conserved, closing in the southwest the Suches lake at about 4,590 m altitude but the morainic sediments extend up to about 4,500 m above sea level.

Between these two glacial groups which are the most developed ones, the evidences of two other glaciers of smaller extension also exist:

- The Ajanani Glacier, whose valley is nowadays being drained by the Ajanani River, extended in its maximum development about 11 km long and the glacier tongue does not seem to have surpassed 1.5 km in width. It is characterized by a complex morainic frontal system where till-flows spread out by the melt waters in overlapping lobules are associated with frontal arches. This system developed over about 6 km2 and its maximal thickness is of about 60 metres. These till-flows lobules descended to about 4,450 m. of altitude.

- The group of glaciers of Guanakokalane-Chuliunkani was formed by short tongues which bearly reached 4 km in length but this group extended itself to 4 km in width.

2.3.2) The different episodes of the Antaquilla Glaciation.

The existence of various glacial episodes is testified by the overlapping of different generations of moraines and fluvioglacial sediments as well as by the conservation of the different systems of morainic arches within the landscape

2.3.2.1) The Torini section and the evidence of the main phases which form the Antaquilla Glaciation.

This section (fig. 7) is found in the Ajanani ravine upstream.

a) At the base, the conglomerates of the Wila-Aja Formation less than 1 m thick, outcrop.

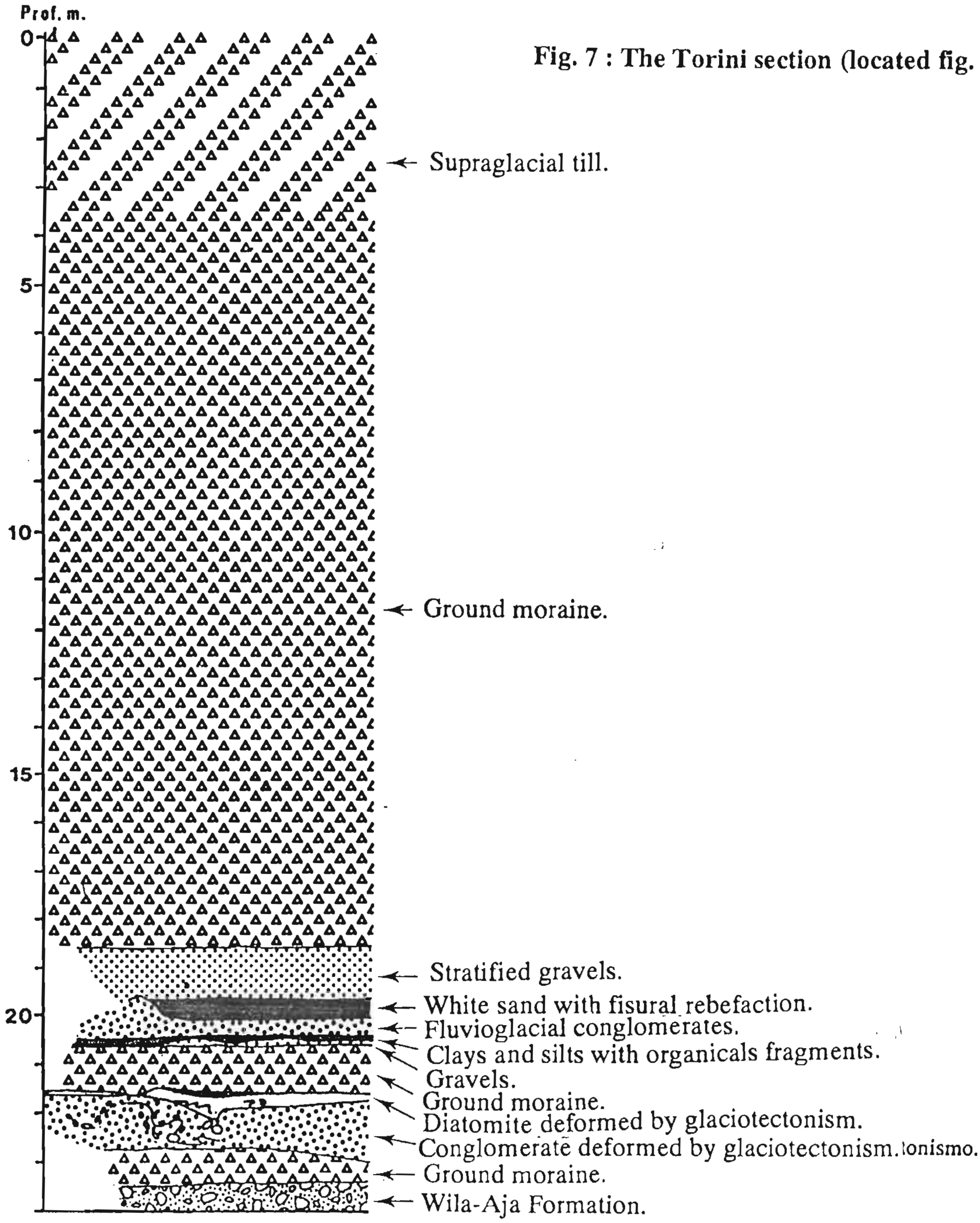

Fig. 7 : The Torini section (located fig. 4).

b) A bed, 0.9 to 1 m thick, of very compact grey till and with abundant sandy loam matrix which corresponds to a ground moraine overlies the Wila-Aja Formation in erosive discordance. The deposits of the Ajanani Glaciation and all the upper part of the paleosoil developed on the Soratera pediment are missing but these structures appear downstream of the described outcrop.

c) A layer, 4 to 5 metres thick, overlies this ground moraine; it is made, from bottom to top, of:

- conglomerates of alternately grey and red colour which is due to a permanence in a hydromorphic environment. These conglomerates are poorly stratified and show clear glacio-tectonic deformation structures. Within the conglomerate, no pebbles presenting glacial strias were found. Towards the bottom, a fragment of about 5 cm in a diameter of reworked peat was sampled for dating but a radiometric C14 age is defined only older than 20,000 years B.P. Towards the top, this conglomerate is covered in a discontinued manner by an accumulation of diatomites with a maximum thickness of 50 cm. In the diatomite, as in the underlying sediments, one can observe clear glacio-tectonic deformations with a vergence towards the south-southwest. Locally, on the summit, clays deposited in shallow puddles are conserved.

- a till with a thickness generally less than one metre. It is composed of pebbles and boulders whose diameter is not over 50 cm. Towards the top, the till passes gradually to conglomerate facies of finer gravel pretty well rounded; its thickness varies from about 10 to about 25 cm.

- a layer of clays, sands and silts with a thickness of about 20 to 25 cm. Its structure is very complex. Locally it is recognized in the bottom traces of hydromorphic soils formed in swampy environments. Over it, outcrop clays deposited through sedimentation in free waters. In these sediments, diminutive vegetal fragments were collected which gave a radiometric C14 age of 23790^{+2620}_{-1990} years B.P.. Towards the summit, in these clays the content of sand and gravel increases.

- a layer of conglomerates of 50 to 80 cm thick composed of pebbles in a sandy matrix deposited in a fluvioglacial environment.

- a set of sand and gravel layers with a thickness of approximately 1.5 metre. This set begins with a layer of white sands with rubefaction developed in vertical fissures. Over outcrops a layer of approximately one metre thick of stratified gravel and stained by alternately grey and red subhorizontal layers formed in a hydromorphic environment.

d) Over this sediment a morainic complex develops composed of:

- at the bottom a layer of grey colored morainic sediments of about 15 metres thick which corresponds to a ground moraine.

- at the top, a bed of grey to beige colored supraglacial morainic sediments the thickness of which is variable (about 5 metres).

In the Torini section, various tills superpose each other. All of which belong to the Antaquilla Glaciation. The upper group forms part of the oldest episodes of the general retreat of the glacier. The intermediary till, older than 23790 years B.P. can be correlated with the arch bounding the maximal readvance of the glacier in the Torini zone. This event produced itself after an important retrocession of the glacier, farther upstream from the point where the studied section is found. During this retrocession, fluvioglacial sediments were deposited which were deformed by glacio-tectonics during the readvance of the glacier forming the terminal arch of Torini. The lower till which overlies the Wila-Aja Formation in the observed section, but which laterally covers the moraine of the Ajanani Glaciation, corresponds to the first phase of the Antaquilla Glaciation whose vestiges are observed to Okoniki-pampa and Chijipampa.

2.3.2.2) Structure of the terminal lobes of the glaciers of Cololo, Suches, Guanakokalane-Chuliunkani and the retrocession arches.

The morphology of the lobe which closes the Cololo lake as well as the stratigrafy of the conserved materials allow to separate various glacial episodes. The multiplicity of the retreat arches shows that the fusion of the glacier was cut by a series of short local readvances. Nevertheless, the structure of the terminal lobe in the region of the Aventura camp and its relationship with the other outcropping terrains show that:

- all these sediments and forms belong to the Antaquilla Glaciation because they overlie the pediment which cuts the sediments of the Ajanani Glaciation.

- previous to the formation of the numerous retreat arches which mark the melting of the glacier, at least two major phases can be individualized and materialized in the zone of the Aventura camp by the juxtaposition of an accumulation of terminal moraines with the morphology of supraglacial moraines and farther inside the remains of ground moraines are conserved. This ensemble is covered upstream by a thick supraglacial moraine which marks the limit of the advance of the glacier in a second phase. Behind it a ground moraine surges whose surface is modeled with drumlin structures and which supports the frontal arches of retrocession. It is possible to separate two different events in the oldest phase considering the morphology of the glacial front between the Soratera River and the Putina pediment even though the arguments are not very clear.

Also in the valley of the Suches lake, one can clearly separate, in the frontal zone, two major phases of fluctuation of the terminal front of the glacier which occupied the valley during the Antaquilla Glaciation. Of the maximal advance, no frontal arch remains but only the termination of the left lateral moraine and morainic flows which reach up to the zone of peruvian-bolivian boundary marker No. 19. On the other hand, a group of frontal arches, extended upstream through clear lateral moraines, closes the Suches lake and corresponds to a second phase of the Antaquilla Glaciation before the general retreat.

The same relative chronology of the glacial events is recognized in the zone of Chiaroko-Guanakokalane-Chuliunkani. The oldest progression phase of the glaciers of the Antaquilla Glaciation is marked, to the west, by frontal arches while between Chuliunkani and Supusupu River we find deposits of supraglacial moraines with small thickness (a few metres) which overlie either the Wila-Aja Formation or the sediments of the Ajanani Glaciation. The frontal arches are clear but of reduced development; they are generally less than 10 metres high. On the other hand, the extension of the most recent phase is underlined by a thicker accumulation of about up to 40 metres of frontal and supraglacial moraine. Much later, the retreat is marked by successive frontal arches at the foot of the mountain.

After an important extension responsible for the edification of the morainic complex already described, the glaciers retreated in the Cordillera valleys. This retreat was not continuous but interrupted by stationary episodes as well as by readvance phases to which we owe the formation of an important number of morainic arches in terrace form in the slopes of the valleys, particularly in the valley of the Cololo lake. Many of these moraines probably have an age older than the beginning of the Holocene (Gouze 1987). Around the 10,000 years B.P., the position of the glacier was at an altitude similar to the present one. At less than 500 m distance of the actual front of the glaciers, organic fossils sampled in post-glacial sediments dated at 8,475 years B.P. were collected in the high valley of Cololo and at 7,470 years B.P. in the high valley of Puyupuyu (Gouze 1987). The most recent movements of the front of the glaciers are clear, they were of small amplitude and they did not have any notable influence on the extensions of the alluvial deposits which may be mineralized.

3) Mineralogical and petrografical composition of the aluvial deposits and implications on the possible distribution of the gold.

From the petrography of the pebbles found in the different moraines as well as from the study of the content of heavy minerals, one can define the different origins of the sediments (fig. 8):

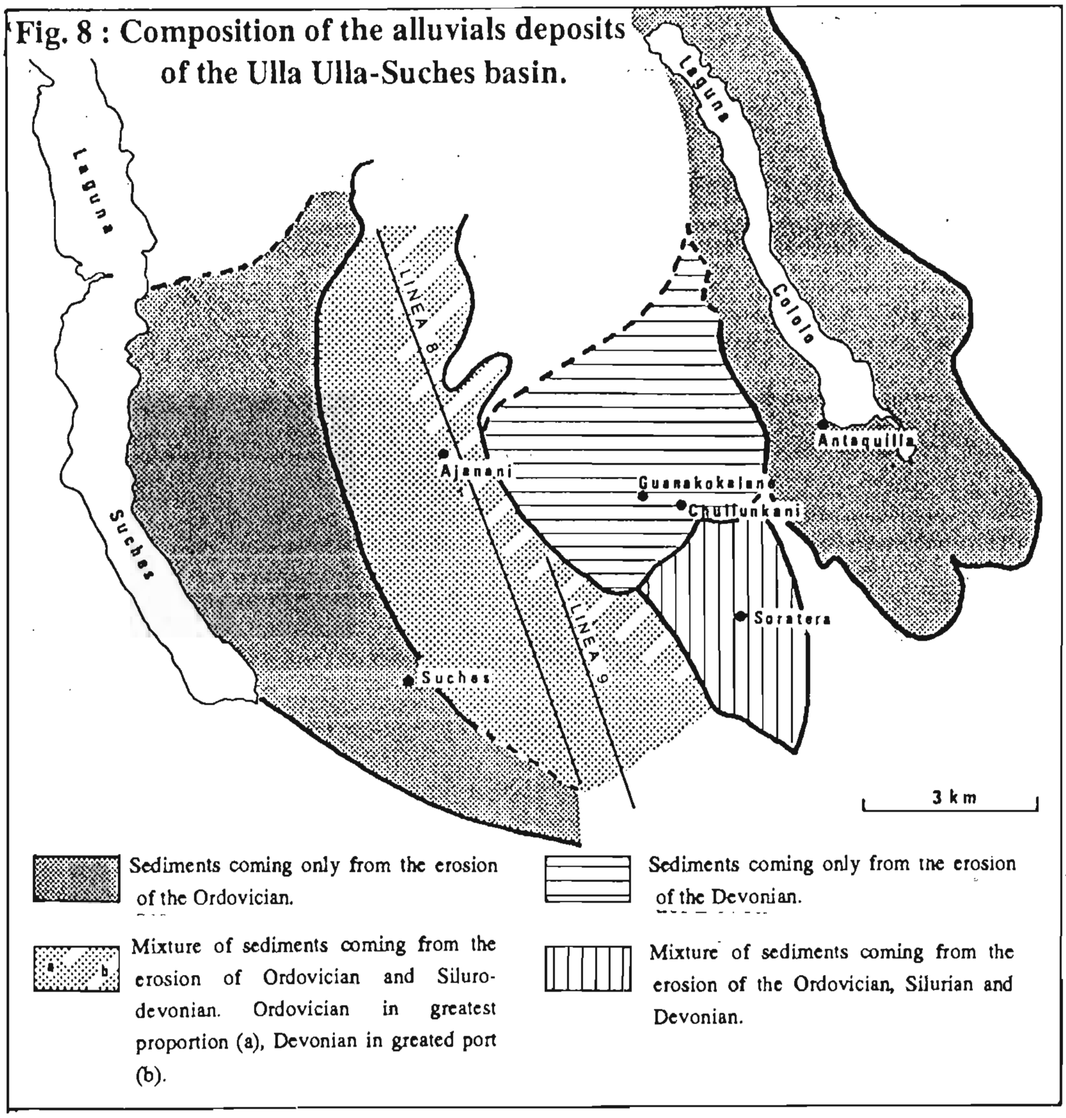

Fig. 8 : Composition of the alluvials deposits of the Ulla Ulla-Suches basin.

- the moraines of the Cololo lake and those of the Suches Lake are composed mostly of pebbles of quarzites and sandy slates derived from the erosion of the terrains of Ordovician age which outcrop in the high part of the valleys (fig. 2). Clast coming from the erosion of the Silurian and mainly from the Devonian are very scarce.

- on the contrary, between Chuliunkani-Guanakokalane up in the valley of the Supusupu River, the moraines are exclusively composed of clasts derived from the erosion of the outcrops of Devonian sandstones and lutites.

- the moraines of the glacier that occupied the Ajanani valley have an heterogeneous composition where contributions coming from the Ordovician and contributions coming from the Devonian mix but in largely variable proportions according to the places. In the left lateral moraine, in an almost exclusive way, clasts from the Devonian are predominant, while in the ground moraine as well as in the frontal arches towards the west, the proportion of clasts coming from the lower Paleozoic increases. On the other hand, the right lateral moraine as well as the frontal moraine to the west of line 9 and the glacial wastage lobes, conserved to the west and southwest of the Ajanani River, are composed mainly of pebbles coming from the Ordovician.

These differences in composition and origin of the material are of great importance because all the terrains from the Paleozoic do not provide gold in the same way. In Perú (Fornari et al. 1982, 1984, Delaune et al. 1989, Hérail et al. 1989) as well as in the Oriental Cordillera in the Northwest of Bolivia (Tistl 1985, Hérail et al. 1988) it is known that in most cases, the primary mineralizations of gold are located in the Ordovician while the terrains of the Devonian and upper Paleozoic are sterile. The mapping of the primary mineralizations known in the Suches-Ulla Ulla zone (fig. 2) shows that these mineralizations are located within the Ordovician. For these reasons, it is very probable that the moraines deposited by glaciers which have eroded Devonian terrains are sterile or very poor while the moraines deposited by glaciers which eroded Ordovician terrains are richer in gold. The same criteria go for the fluvioglacial phases.

As to the formation of the Wila-Aja, one must underline that it is composed of a mixture of contributions coming from the lower Paleozoic as well as from the upper Paleozoic and that the sediments have been deposited in environments of middle or low temperature. In general these factors are unfavourable for the concentration of heavy minerals and for gold in particular. Besides that, on the Peruvian side, in Ananea, it was shown that the Formation Arco-Aja, of the same composition and same age, is sterile or very poor in gold content (Hérail et al. 1989, UNRFNRE 1990).

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