Figure 4: *Base of the polishing rotating table installed in its pit. The oil pads at the periphery of the table base are protected by grey yellowish plastic. The track is attached to the table.*

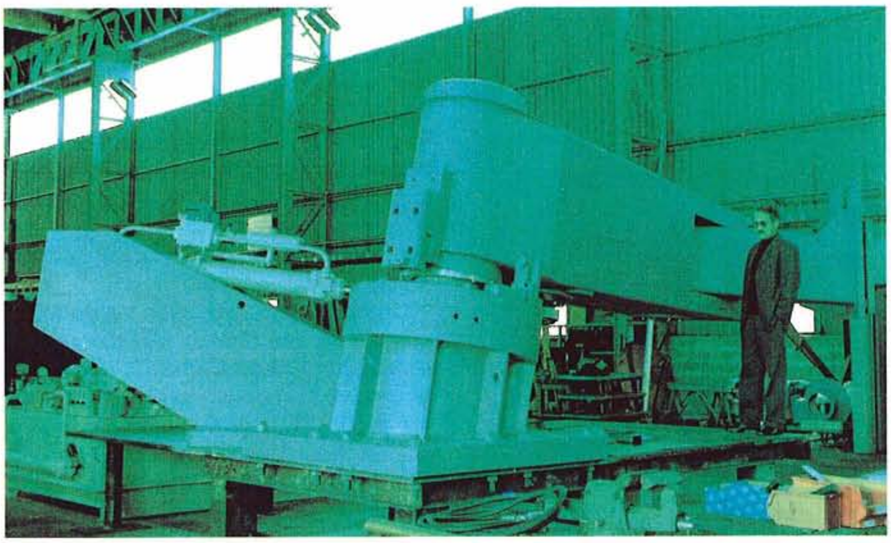

Figure 5: *The polishing robot in Bordeaux.*

tion is given to the need to maintain the summit of the mountain free from any source of disturbance for the observations.

In Denmark, COWIconsult is completing the design of all civil engineering complexes both in the hotel area and the telescope area and is preparing the technical specifications for the call for tenders that will be sent out in spring 1992. It is interesting to note that a major effort has been devoted to the requirement to keep underground all the infrastructure such as the laboratories and interferometry tunnel which need to be kept in stable thermal conditions. Another area of careful study was to create easy access to the different buildings during observation and also to simplify the transport of large pieces such as the mirror cell. In the hotel area the need to create a pleasant environment for the Paranal population has been one of the goals of the design of the offices, hotel facilities and dormitories. Also the design of the interior both from the furniture point of view and the colour scheme are part of this work and will help considerably in the future life at the observatory.

In France IRAM and STEC are collaborating in the detailed design of the VLT enclosure. A concept of a carousel type was chosen, fulfilling all the requirements of the astronomical community and giving good protection of the telescope from any source of disturbance. At the same time more analyses are being done on the effects of earthquakes on such large structures, and a wind tunnel study is foreseen to optimize the ventilation of the enclosure to reduce the dome seeing to zero.

In Italy AES is continuing the first phase of the telescope structure contract which will culminate in the preliminary design review in summer 1992.

The work done so far has concentrated on the definition of the critical components such as the direct drives which are a peculiar characteristic of the VLT, the hydrostatic bearings and the encoder system for which various technical solutions are being considered. After the preliminary design review the project foresees the detail design review for the rest of 1992 and the start of the construction early 1993. The plans for the erection in Chile in 1995 of the first telescope is confirmed and will be preceded by extensive tests of the telescope erected in Europe.

A Geological Description of Cerro Paranal or Another Insight Into the "Perfect Site for Astronomy"

*F. BOURLON, ESO**

Paranal, where the ESO Very Large Telescope project is situated, is not just any old place! It is unique because it is *the* "perfect site" for astronomy. But it is also unique because of its location in the Atacama desert. It is a place of character by its remoteness, its loneliness and its desolation. Nevertheless, it is also a place of beauty by its colours, its silence and its space. No one who comes here is left unmoved by the spectacle that unfolds in front of his eyes. Yet if we stay here long enough we realize that there is still more. There is something "deeper", something that emerges from the land and earth itself. As our perceptions become sensitized

* Editor's note: Fabien Bourlon is a French geologist working as coopérant with the VLT Site and Building group at Paranal.

by the silence, we take notice of the forms, shapes and colours of every object that is present. Smooth hills roll off to the faraway Andes... The mountain range to which Paranal belongs slopes down to the west and falls dramatically into the Pacific Ocean. Cliffs and canyons cut deep into the earth in a complex manner.

While Paranal watches over the great Pacific Ocean to the west, the silent Atacama desert and the Andes to the east, questions come up. What gave rise to the round and smooth morphology of the area? What is this land made of? What dramatic events occurred to mark this place with cliffs, canyons and abrupt valleys?

In the field of Geology these questions relate to three different themes; "Morphology and Geoclimatic Activities", "Geodynamics" (or "Plate Tectonics") and "Petrography" (or "Rock Constituancy").

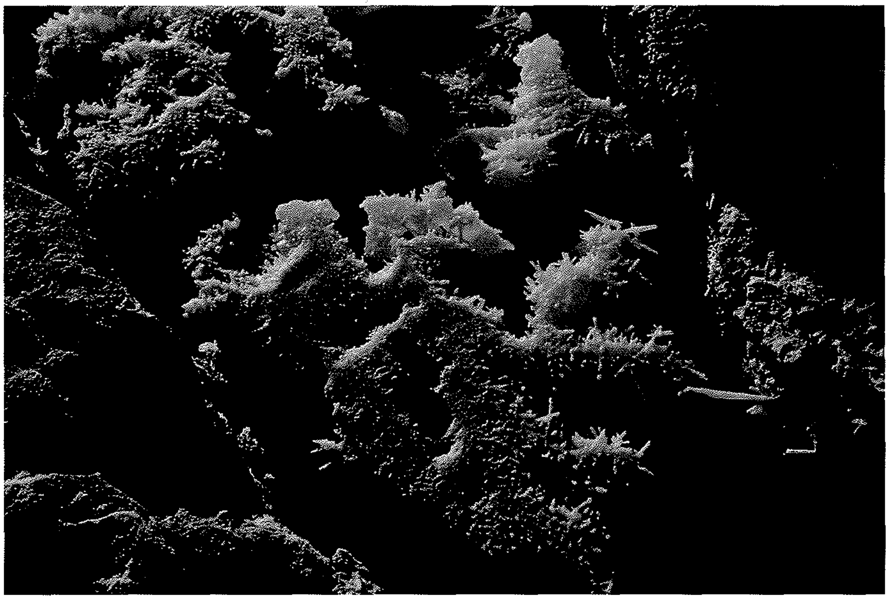

Figure 1: *Crystals of salt in a rock fracture. Such pure forms are found on the shores of "salares" (salt lakes).*

Morphology and Geoclimatic Phenomena

The landscape of Paranal is smooth and round. Hills and small mountains can be seen to the north, the south and the east. There are rocky outcrops only near the ocean coast. A wide valley, where the old Panamericana or "B70" road lies, runs almost north-south. It is bordered by hills. Boulders can be seen in the valleys or on their slopes. Some darker material spreads out on top of the general beige surface of the hill's slopes.

What first attracts the eye is the aspect of the landscape, the presence of big lonely boulders and the large deposits of eroded and alluvial material. It is puzzling to find here the marks of erosion linked to rain and water activity when we consider that we are in the Atacama desert. It is surprising but the reason is that the climate of the area has changed drastically in the last 10,000 years. Studies have shown that at a time the climate was of a glacial period. Glaciers rushed down from the high Andes to the interior valleys. The land was covered by numerous large lakes. The salars, antique lakes that have dried leaving large deposits of salt, are the clearest mark of that epoch. The Paranal zone had certainly no such glaciers because of its location near the ocean, but abundant rain and snow falls affected it. This climatic environment induced important rock alteration and modelled the landscape. The succession of heat and cold structured the rock, and the water circulation carried away material, depositing it in the valleys in the form of sands or boulders. Due to the marine air, salts (sulphides and chlorides) were deposited and then crystalized in the rock massif (Fig. 1).

At a later period the landscape was further shaped by drastically different climatic conditions. Rains became more seldom, the glaciers melted and the land dried out giving rise to the desert we know today. In this environment occurs a specific type of phenomenon called "arid weathering". It excludes movement of material except by wind effects and it mainly affects the rock's structure itself. Minerals of lesser resistance such as micas and felspars are altered into clays. The more resistant minerals such as quartz and amphiboles or pyroxenes are left uncemented and the rock loses its coherence. This phenomenon is known as "arenization" (transformation into sand) and is common in all granitic regions. Figure 2 shows the rock at the Paranal summit in such a state of decomposition. There is sand on the top layer, round large boulders below and then deeper down the still sound rock. In the current levelling works of the Paranal summit this has been described as the "weathered layer" zone. On average it constitutes the first 6 m of at the Paranal surface. This "soil" is easily removable and, for construction purposes, is unstable.

However, the two climatic phenomena that have been described – hydraulic weathering and arid weathering – do not fully explain the observed landscape.

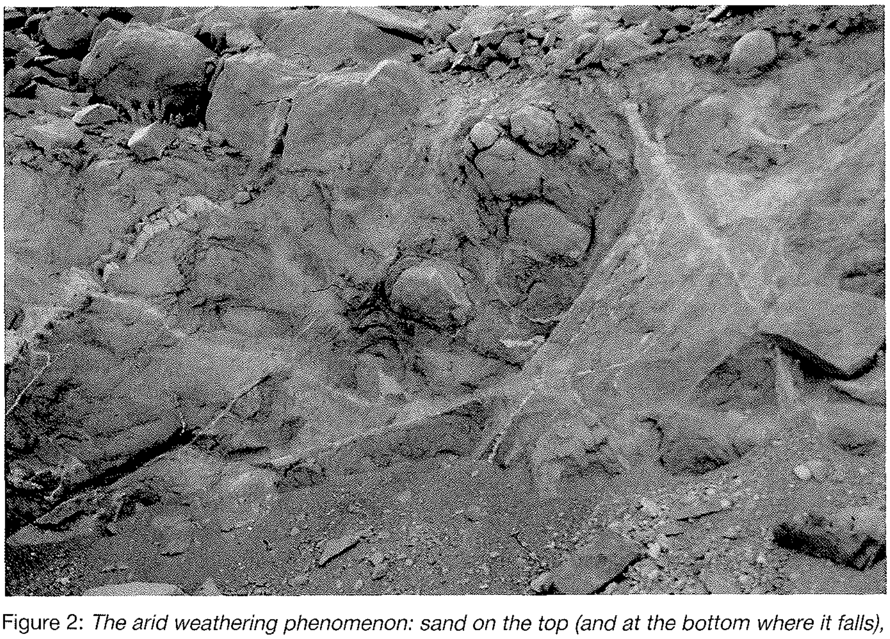

Figure 2: *The arid weathering phenomenon: sand on the top (and at the bottom where it falls), round boulders and the "sand" rock. White, salt filled, fractures can also be seen.*

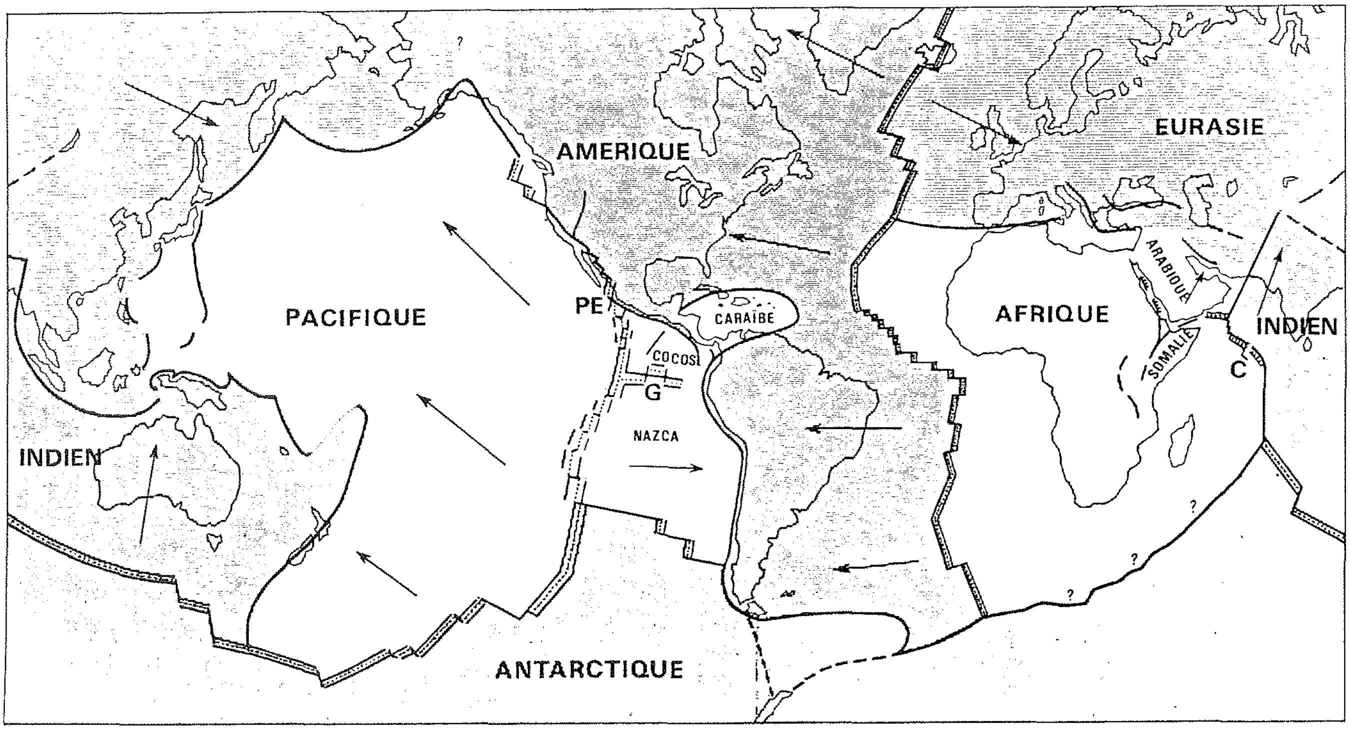

Figure 3: *Drawing showing the six main plates and some secondary ones. The movement of the plates is given considering that the African plate is immobile. The plates are generally limited by oceanic rifts or abyss. G. Galapagos rift, PE. East Pacific rift, C. Carlsberg rift. (E. Bullard modified, 1984).*

Obviously these two phenomena affected a pre-existing surface. The origin of the relief has to be linked to that of the Andes range. In reality it is a complex geological context that gave birth to this land.

Geodynamics, Plate Tectonics and the Formation of the Andes

When we stand on the summit of Paranal, looking from east to west we see the cliffs and canyons bordering the coast, a valley, a range of hills, a wide valley called Pampa Remendios on a new mountain area. We then usually take notice of the high Andes that spread far away to the east. On the horizon rises the majestic volcano Llullaillaco, with its 6738 m one of the five highest volcanos of the world.

Geographically speaking, various units constitute the Andes; the coastal mountain range ("Cordillera de la Costa"), the interior massifs (such as the "Cordillera Domeyko" or the "Sierra de Vicuna Mackenna" in the Antofagasta region) and the high range which constitutes the "Cordillera de los Andes". The Paranal mountain belongs to the Cordillera de la Costa, and is its highest point with its 2664 m. Armazones on the other hand belongs to the Sierra de Vicuna Mackena (3064 m).

The layout of these units has a logic. The Andes chain, as a whole, is the result of what is called "Plate Tectonics". The mobility of the earth crust provokes, on the scale of geological times, intense deformations that give rise to mountains in certain parts of the globe. The younger mountain ranges are situated at the boundary between a continental and an oceanic mass. In Chile the two plates that meet are the oceanic Nazca plate and the continental American plate (Fig. 3). The plunging of the Nazca plate below the South American continent is known as the Subduction phenomenon. Just like the bodies of two cars that bend as they collide, the continental South American mass and the oceanic Nazca mass bend and "fold" as they meet (Fig. 4). The folds correspond to the "Cordillera de la Costa", the "Cordillera Interior" and the Andes. This collision, and thus the formation of the Andes, began in the triasic period (225 million years ago) and continues at present (horizontal movements are estimated at 10 cm/year and the vertical ones at 2 cm/year). In comparison the formation of the Alps started in the Trias (225 MY ago) and ended during the Pliocene (7 MY ago).

The formation of these mountains induce seismical and volcanic events. The two plates in a "dead-lock" accumulate strains until the rock breaks. The plates fracture across their whole width releasing energy as shock waves. Material in fusion, situated in the earth's mantel, using the previously created fractures, flows to the surface. Lava is released in a volcanic eruption. The volcano Llullaillaco was formed that way.

These geological events moulded the landscape. In the Paranal area for example, the valleys that border the mountains or the cliffs that border the ocean correspond to faults caused by the plate's dynamics. The tens of kilometres long "Salar del Carmen" and "Izcuna" faults, located east and west of Paranal, are the borders of blocks that moved in opposite directions. Because of this dynamic the zone in which Paranal stands was literally crushed. Studying the rock at the summit of the mountain we find that it is density fractured. It was further affected when water circulation increased its erosional effect. Each fracture rendered the rock more vulnerable to weathering. As we look at the geological chronography of this land we understand the history of the modelling of the landscape. The same applies when we study the rock composition of Paranal. It is in this geodynamic context that the petrography has to be considered.

The Paranal Rock Formation

Basically three types of rock are found on the Paranal hill; Gabbros, Andesite and Granodiorites (Fig. 6).

The *Gabbro* is a dark gray rock of large-sized minerals, mainly Felspars (alumino-silicas) and Pyroxenes or Amphiboles (ferromagnesian minerals). It contains very little or no quartz (silicium). A rock containing somewhat more quartz and having a different proportion of Felspars types is a "Diorite". Because

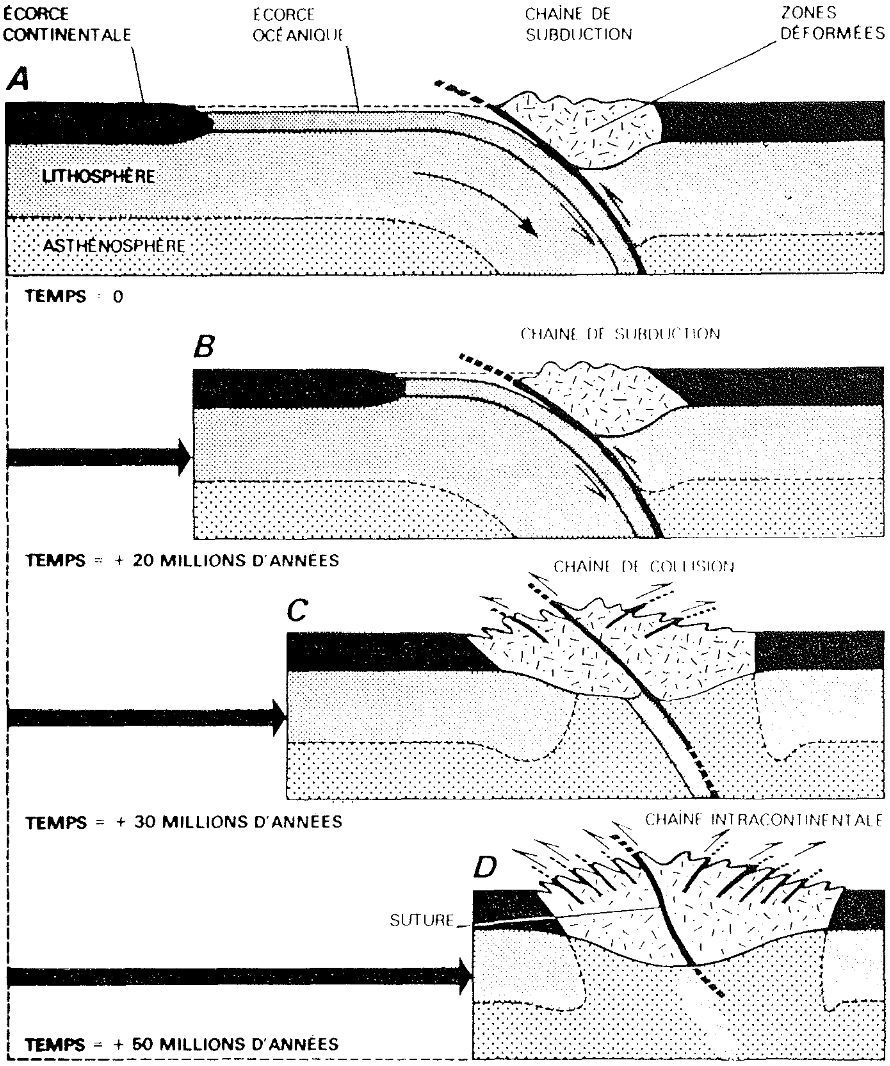

Figure 4: *Geodynamic evolution of plates in a "Subduction" zone. The time scale is only indicative. In the Nazca Plate/American plate zone, movements are estimated at 10 cm/year. (M. Mattauer, 1981).*

these chemical variations are common we sometimes speak of the "Gabbro-diorites" of Paranal.

The *Andesite* is a dark-green rock. It contains some Amphiboles (green-black ferromagnesia), very little Felspars and silicium in its amorphic form (glass). Its texture is fine and the minerals that constitute it are almost invisible. They are basalts, just like the Gabbros but have had a different formation context (lower temperatures and lower pressure). Basically the Andesite is a "surface" type of rock and solidified in a rapid way, while the Gabbro is a rock of high depth that solidified slowly. A slow cooling enables the growth of crystals (like those that are found in Gabbros), while a rapid cooling produces glass. This rock is usually found in volcanic areas.

The *Granodiorites* is a pinkish type of rock. It contains Plagioclases (a type of felspars, pink or white in a non-altered state) and quartz in a lower measure than in a Granite. It also has the textural name of "Aplites" because of their dense but very fine mineralization.

Figure 7 is a schematic association model for basaltic types of rock. On a scale that goes from some thousands of metres down up to the surface and that relates to a pressure and temperature scale, we can locate the Gabbros at medium depth and Andesites at surface level. The granodiorites are located in "Dykes" or "chimney"-like ducts that cut across the Gabbro. The Andesites can also be found in such a state (as is the case at Paranal). Simplifying one could say that the three types of rocks formed here originate from the same magmatic

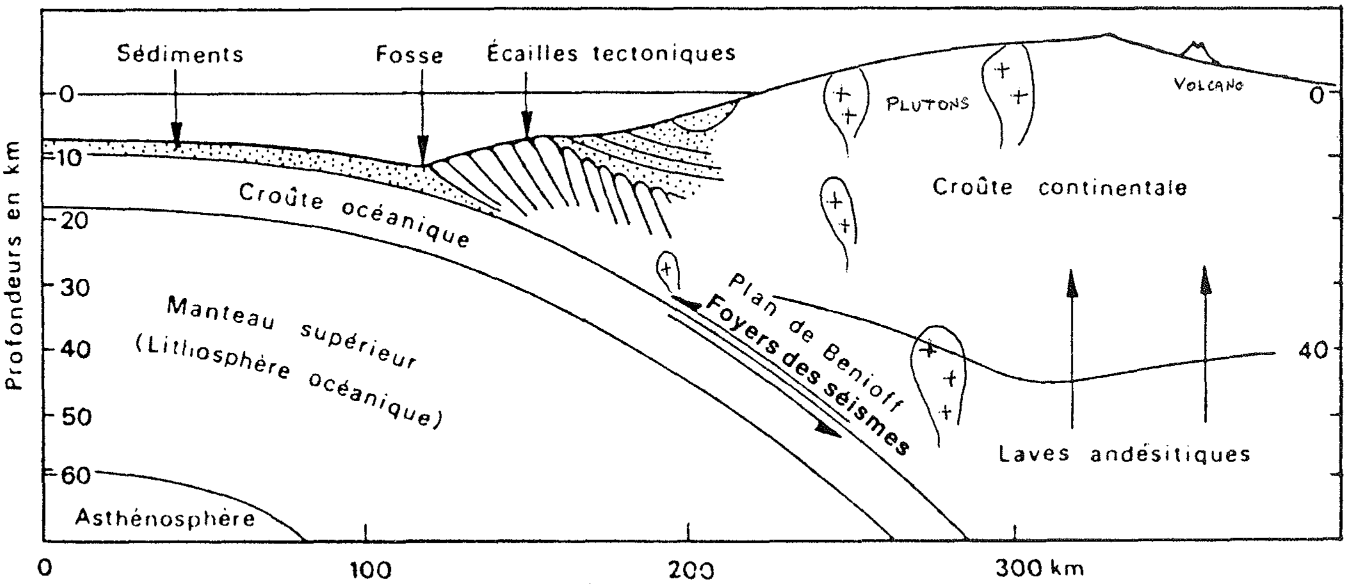

Figure 5: *Simplified cross-section of the earth crust at the occidental limit of South America (heights are exaggerated). The subduction of the Nazca plate carries earth crust and sediments down to the earth's mantel. Dehydration of the sediments liberates fluids that can cause partial fusion of the above crust. The material in fusion rises towards the continent's surface. As the material cools it crystallizes giving plutons (granitic masses). The material can also reach the surface as a lava. (Le Pichon, modified).*

Figure 6: *These are the typical rocks found on the Paranal summit; the black "Gabbro", the green "Andesite", the pinkish "Granodiorite", the green-blue copper minerals, two samples of "salt"-enriched rocks (white), a metamorphic rock with fern-like deposits of magnesium and in the centre a green-gray rock containing "Olivine" crystals.*

liquid but then evolved in different temperature, pressure and chemical environments.

Clays are occasionally found. As previously explained they originate from the alteration of the felspars contained in the rocks.

There are a few particular minerals. Such as chlorides or sulphides. Salts that were deposited in recent times by weathering effects. There are also some "rare" minerals such as Copper and Olivine. Copper is found associated to different chemical complexes and three types are found here; Atacamita, Crisocola and Calco-pyrite. These deposits are related to hydrothermal fluids, minerally charged, that circulated in present faults. Olivine on the contrary is of high temperature and pressure context and so of great depth. The rock containing such a mineral was probably brought up from deeper rock layers.

If we enlarge our scale of analysis, the geology of the area appears more complex. As we can see in the geological map (Fig. 8), sedimentary deposits (marine sediments of calcareous type), sandstones (marine or lake deposits of silicium type), intrusive rocks (typically a Granite) or mylonites (a metamorphic rock) have been found. This conglomeration of so many different types of rock, formation wise, is due to the geodynamic phenomena of the zone. The upheaval of the Andes has put into contact and intricately mixed all types of rocks. Faults and kilometre long movements have displaced blocks or enabled material from the earth's core to rise. Heating has transformed material. Friction and fracturing linked to tectonic movements affected the entire land.

Intellectual Interest and Practical Applications

Studying the geology of Paranal gives us a new vision of the site. One can really be awed by the history of the modelling of this land. But beyond the intellectual interest, this knowledge is useful. Understanding the geology of Paranal is necessary to plan the construction of the VLT. Soil mechanic studies, seismic hazard estimates, water use programmes or researches for construction materials rely fully on the correct understanding of the site's geologic or geotechnic characteristics. Knowing about the rock composition is helpful when searching for adequate sands or gravels for concrete. Understanding the recent geo-climatic environment can orientate the water supply programme. Estimating the seismic hazard risk, by statistical studies of occurred events or by monitoring seismic tremors, enables the structural design of the buildings. Testing the geotechnical quality of the Gabbros, Andesites, Granodiorites or the surface material, gives indications as to where to install and how to design the buildings' foundations. This in accordance to the resistance and stability of the terrain in such a seismic prone zone. In all, the geological understanding of the place is of vital interest. Particularly if we consider that the biggest telescope ever is being built here!

Acknowledgements

I thank S. Dunn for re-reading and correcting my "Franco-Spanish" English, and P. de Jonge and J. Eschwey of the VLT site building group for their interest.

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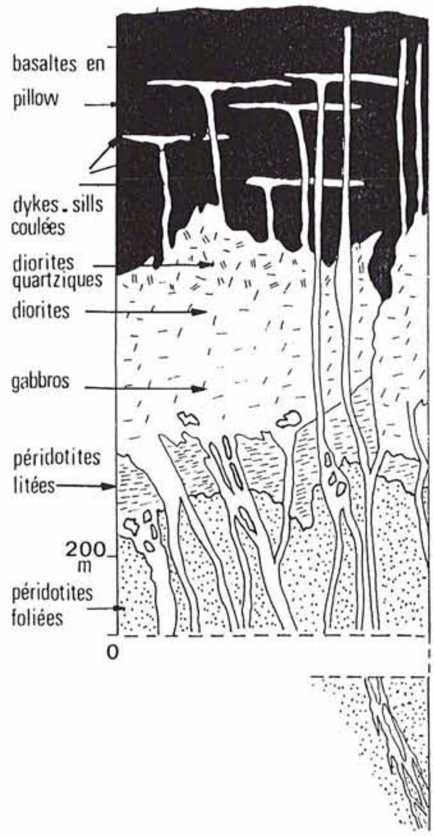

Figure 7: *Model of association of basic to ultra-basic rock occurring supposedly below the sea floor. (J. Dercourt, J. Paquet, 1985).*

Tentative Time-table of Council Sessions and Committee Meetings in 1992

May 4–5	Users Committee
May 11–12	Scientific Technical Committee
May 25–26	Finance Committee
June 2–3	Observing Programmes Committee, Amsterdam
June 4–5	Council
November 12–13	Scientific Technical Committee
November 16–17	Finance Committee
November 26–27	Observing Programmes Committee
December 1–2	Council

All meetings will take place in Garching unless stated otherwise.

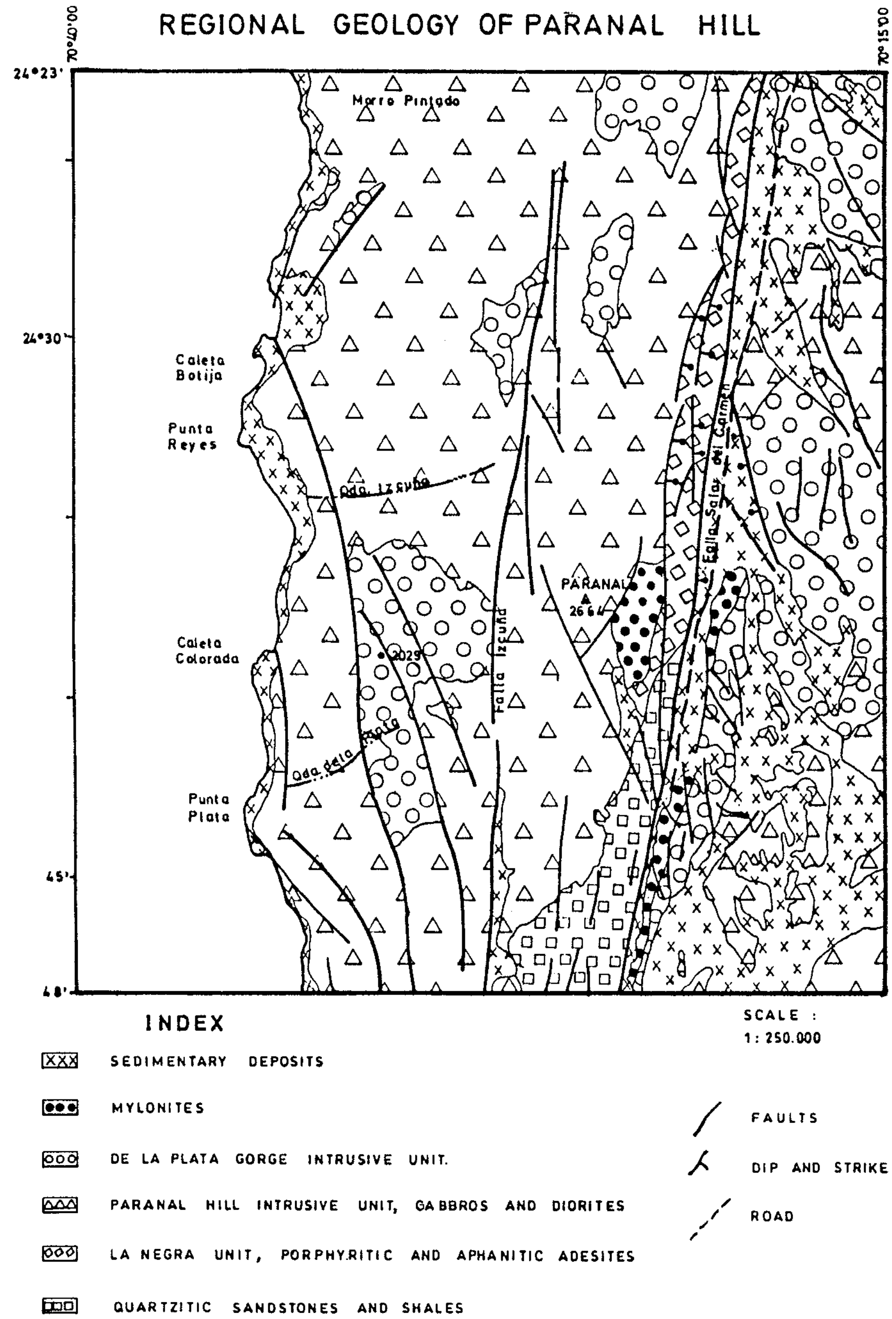

Figure 8: *Regional Geology of Paranal Hill. (F. Ferraris, 1978).*

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Figure 3: As found in Bellair P. and Pomerol C., 1984, *Eléments de Géologie*, page 108.

Figure 4: As found in Bellair P. and Pomerol C., 1984, *Eléments de Géologie*, page 132.

Figure 5: As found in Bellair P. and Pomerol C., 1984, *Eléments de Géologie*, page 110.

Figure 7: As found in Dercourt and Paquet 1985, *Géologie, Objets et Méthodes*, page 50, chpt. 4.

Figure 8: As found in Piddo J., 1990 "Geotechnic-Geological Study of Vizcachas and Paranal hills" ESO report, Annex, plate 2.

New ESO Preprints

(December 1991 – February 1992)

Scientific Preprints

803. E. Giraud: The Environment of 3C 255. *Astronomy and Astrophysics Letters.*
804. E. Giraud: Morphology of Faint Blue Galaxies. *Astronomy and Astrophysics* Research Note.
805. F.R. Ferraro, F. Fusi Pecci and R. Buonanno: The Galactic Globular Cluster NGC 5897 and its Blue Stragglers Population. *Monthly Notices of the Royal Astronomical Society.*
806. F.R. Ferraro et al.: On the Giant, Horizontal, and Asymptotic Branches of Galactic Globular Clusters. IV: CCD-Photometry of NGC 1904. *Monthly Notices of the Royal Astronomical Society.*
807. P.A. Mazzali, L.B. Lucy and K. Butler: Barium and Other S-Process Elements in the Early Time Spectrum of SN 1987A. *Astronomy and Astrophysics.*
808. P. Padovani: A Statistical Analysis of Complete Samples of BL Lacertae Objects. *Astronomy and Astrophysics.*
809. P. Ruiz-Lapuente, L.B. Lucy and I.J. Danziger: The Use of Nebular Spectra of Type Ia Supernovae for Distance Determinations. The Distance to the Centaurus Group.
     P. Ruiz-Lapuente et al.: Spectroscopic Differences Among Type Ia SNe and their Use as Standard Candles.
810. D. Baade: Nonradial Pulsations of O- and B-Stars. Invited Review presented at the Kiel-CCP7 workshop on "Atmospheres of early type stars" and to appear in the proceedings edited by U. Heber and C.S. Jeffery (Springer, *Lecture Notes in Physics).*
811. P. Ruiz-Lapuente et al.: Modeling the Iron-Dominated Spectra of the Type Ia SN 1991T at Premaximum. *The Astrophysical Journal* (Letters).
812. J. Surdej et al.: Optical Observations of Gravitational Lenses. Invited paper at the "Hamburg International Conference on Gravitational Lenses", (Hamburg, Sept. 9–13, 1991). To appear in the Conference Proceedings, Springer, *Lecture Notes in Physics* series.
813. P. Magain et al.: Q 1208+1011: The Most Distant Multiply Imaged Quasar, or a Binary? *Astronomy and Astrophysics Letters.*
814. Bo Reipurth and S. Heathcote: Multiple Bow Shocks in the HH34 System. *Astronomy and Astrophysics.*
815. L. Pasquini et al.: Detection of Strong Chromospheric and Coronal Activity in Pop II Binaries.
     L. Pasquini and E. Brocato: Chromospheric Activity and Stellar Evolution: Clues from IUE Data.
     R. Pallavicini et al.: A Low-Resolution Spectroscopic Survey of Post-T Tauri Candidates.
     G. Tagliaferri et al.: Optical Spectroscopy of Cool Stars Detected by Exosat.
     G. Cutispoto et al.: Photometry of Serendipitous X-Ray Sources.
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816. M. Forestini et al.: Fluorine Production in the Thermal Pulses on the Asymptotic Giant Branch. *Astronomy and Astrophysics.*
817. A. Jorissen and M. Mayor: Orbital Elements of S Stars: Revisiting the Evolutionary Status of S Stars. *Astronomy and Astrophysics.*
     A. Jorissen: Orbital Elements of a Sample of S Stars: Why are they not Symbiotics? Paper presented at the "XIII^{e} Journée de Strasbourg", Advanced Stages in the Evolution of Close Binary Stars", ed. G. Jasniewicz, Strasbourg, 1991.
818. M.D. Johnston and H.-M. Adorf: Scheduling with Neural Networks – the Case of Hubble Space Telescope. *J.*