THERMAL ALTERATIONS OF THE ASHUA FORMATION AT THE CONTACT WITH A PORHYRY INTRUSION (HUAMBO, SOUTH PERU), A RECONNAISSANCE STUDY

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INTRODUCTION

In the Western Cordillera, Huambo district, Arequipa province, a prominent porphyry stock intrudes Upper Cretaceous redbed fluvial-evaporate formation (named Ashua by Cruz, 2002) and its predecessor, essentially shallow marine limestones of the Arcurquina Formation. Both the petrography of the porphyry and hosting formations as well as the contact phenomena are not described as yet. They are the subject of the present article.

It is a signal of broader research on contact alterations in the Huambo district, conducted by the Polish Scientific Expedition to Peru (Paulo & Galas, 2011), which are prepared for publication. This shall enrich relatively poor literature on thermal phenomena in evaporate formations.

Most of the field observations and mesotectonic measurements come from a large quarry at the altitude 3850-3950 m a.s.l. at the road Pedregal – Huambo, the nearby roadcut into Ashua Formation, and Quebrada Rodriguez, exposing all three lithostratigraphical units. Laboratory investigations included traditional microscopy of thin sections in polarized light, the additional studies of fine grained samples in the scanning electron micropscope (SEM) as well as X-ray tests.

ARCURQUINA FORMATION

In the investigated area only upper sequence of the Arcurquina Formation, corresponding to Cenomanian and Turonian are exposed. Bioclastic limestones and marly limestones reveal significant share of angular grains of quartz and alkali feldspars and admixture of biotite, chlorite and titanite. It suggests short transport of acid pyroclastic material. In dark, fractured limestones gypsum veinlets occur, while in accompanying mudstone stripes of automorphic pyrite or goethite pseudomorphs after pyrite are present. In the upper section of the profile zoogenic limestones (Fig. 1e) are intercalated by greenish clastics. They are quartz-calcite (coquina) sandstones and marls containing quartz, albite, glauconite, clinochlore, and illite. The Arcurquina Fm. is unconformably covered by the series of red mudstones, marly limestones and evaporites of the Ashua Formation. The unconformity was documented with mesotectonic measurements in the both members.

ASHUA FORMATION

The Ashua Formation is of local extent. It was described in detail in four profiles and redefined by M. Cruz (2002). The descriptions of the Ashua Fm. known to us so far are based exclusively on megascopic observations and palaeontological examinations of marine fauna present in limestone intercalations. Fossils found there indicate a time span Coniacian – Early Santonian (Jaillard et al. 1994). This was followed by a longer pause in sediment accumulation. Ashua Fm. is unconformably superposed by continental Huanca Formation which formed since Eocene.

Alternating layers of red mudstones and sandstones prevail in the sequence, which in the studied area are 300-350 thick. They are intercalated by lensoidal conglomerates, limestones, marls, gypsum, and locally rock salt. Subordinate are strata or laminae of fine clastics green, grey or yellow in colour. Sedimentological features indicate gradual change from marine and endoreic lacustrine environments into alluvial one upwards (Cruz 2002).

Our studies show that in the upper part of Quebrada Rodriguez, at the base of the sequence, a set of red mudstones intercalated by marly limestones and stromatolithic limestones occurs.
Detrital material contains some 5% of angular quartz, albite, chlorite, smectite, biotite, and magnetite altering into goethite. Accessory are allanite, zircon and hematite. In brecciated limestones infiltration halite is present. Above these deposits a layer of grey gypsum with calcareous intercalations appears reaching several ten metres. The layer is capped by red mudstones containing a lens of white and grey rock salt, attaining some 2 metres in thickness. Microscopic plates of anhydrite are dispersed within halite, and streaks, and small jacks of red clay and black substance occur. The clayey fraction consits of quartz, calcite, illite, hematite, vermiculite and clinochlore. The rock salt is exploited in primitive Rodriguez salt mine.
In the distance of 500 m from the mine a large apophysis of dacite stock is exposed forming a sheer wall. No thermal alterations were observed in the rock salt. However, the contact of the dacite apophysis with the Ashua Formation in the vicinity of the salt mine abounds in landslides and was not studied in detail yet. Such investigations were carried out in abandoned quarry of porphyry above the entrance to the terminal tunnel of the Majes Project in Ashua.

PORPHYRY STOCK

Porphyry forms marked intrusion 30 km long and some 3 km wide. It forms local watershed ridge between Quebrada Jaran depression and Rio Huambo passing into source region of Rio Seraj.
To the east the intrusion hides below Pleistocene cristalloclastic tuffs of the Ampato volcano and contacts with the Paleogene Huanca Formation (Palacios 1991).
The porphyry intrudes in the western wing of a syncline filled with the Ashua Fm. and metamorphoses it along the contact. At the side of Jaran it contacts also with the Arcurquina Fm. However, the latter contact is mostly tectonic, postintrusive. Relation to the Huanca Fm. is unclear due to extensive alluvial cover, and party tectonic, as figured in the cross section to the map of Chivay (Quispesivana & Navarro 2001). We cannot confirm the Chejol stock crosscutting the Huanca Formation, what Huaman (1980) noted at Cerro Pallanca. It was an important argument in the interpretation of the intrusion age as Eocene or younger, according Huaman even Miocene. On the other hand, Caldas (1993) stated that in Ashua, i.e. close to Cerro Pallanca, the conglomerates of Palaeogene Huanca Fm. do not show any thermal alterations. On this basis he accepted that the stock in question was intruded during Peruvian phase, at the turn of Cretaceous and Palaeogene. Nevertheless, Quispesivana & Navarro (2001) named the rock tonalite and by analogy to the row of Yarabamba intrusions, which are related to the nearby Incapuquio-Quellaveco fault zone and Toquepala volcanics (Zimmermann & Kihien, 1983, Alejandro et al. 2006), they ascribed to the stock Eocene age.

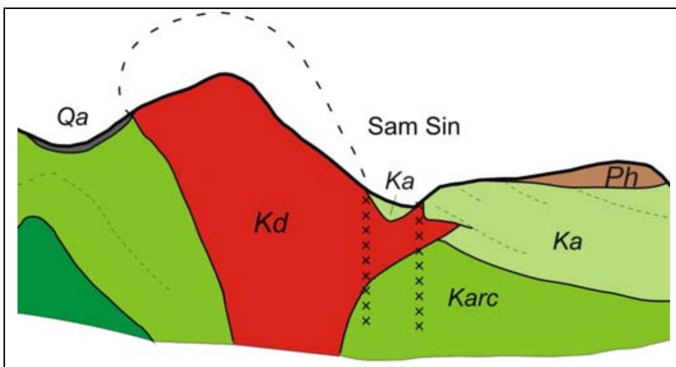

Fig.1. Cross section of the porphyry stock at the quarry

Qa – Quaternary alluvia and deluvia, Ph – Paleogene Huanca Formation, Kd – Late Cretaceous/Paleogene porphyry, Ka – Late Creataceous Ashua Fm., Karc – Late Cretaceous Arcurquina Formation,
xxx – mylonitized zone

Near Ashua, at the edge of young Huambo tectonic depression, the porphyry apophysis drops out, being some 500 metres wide and 4 km long. It goes to the upper part of Quebrada Rodriguez. In the vicinity of the intrusion branching sandy beds of the upper part of the Ashua Fm. are more compact, fractured and cut by veinlets of white and colourless zeolites. Zeolite veinlets, mostly greenish, cut porphyry as well. External part of the intrusion is mylonitized and bleached in a narrow zone 0,2-1 m wide along with surrounding rocks. Fresh rock is classified as porhyric phenodacite, with phenocrysts of white plagioclase, quartz, amphibole and black mica.

As follows from the review of bibliography there is also unequivocal determination of the rock. Caldas (1993) in his explanations to the Huambo sheet of the geological map uses name hipabissal porphyry (dacite) but in the legend of the map itself the name tonalite appears. Hosttas (1967) referring to the microscope analysis abroad uses the term porphyrite (quartz andesite). Huaman (1980) noticed compositional differences in distant outcrops of the intrusion classifying the rock (despite finding glass) as porphyric microgranite.
Under microscope dacite in question shows 45-50% phenocrysts, in it almost 40% leucocratic (intermediate plagioclase, alkali feldspar and quartz) and 5-10% mafic (pargasitic hornblende, phlogopite, sporadically acmite-augite). The matrix in the samples studied by us is finegrained but holocrystalline. It contains the same minerals as phenocrysts and accessory magnetite, ilmenite, hematite, titanite, apatite, allanite, zircone. Iron and titanium oxides associate with amphibole and mica forming numerous inclusions in them. Hematite tabular aggregates are frequently pseudomorphic after magnetite. Colour index usually 15-20%. Some plagioclase grains are zonal, albitized at phenocryst rims. XRD analysis determined disordered intermediate Na-Ca members as well as well-ordered albite. Some zones are party altered in sericite aggregate while others appear chloritized.

ALTERED ROCKS

In the quarry above Ashua the dacite apophysis is mylonitized and altered into bleached spotty rock. The mylonite abounds in zeolite veinlets in a zone 1-2 metres broad. Western mylonitic zone contains also fragments of roof pendants representing limestones and detritic rocks of Ashua Formation. Eastern mylonitic zone, worse exposed, seems to accompany the foot of the apophysis close to the course of the road Huambo-Pedregal to the south of the quarry and Quebrada Sam Sin to the north of it. However, northern part of the second zone near road bridge exposes steep contact of white mylonitized dacite and red Ashua mudstones which are also tectonized and altered. Dacite in the centre of the quarry, i.e. in the central part of the apophysis seems unaltered or reveal only weak albitization, K-feldspatization and zeolitization of plagioclases. However, at megascopic inspection, some joints are filled with semitransparent or white radial zeolites (stellerite, stilbite), bluish-black Mg-riebeckite or red-brown K-richterite and green chlorite. Locally dark needles of tourmaline (dravite) are encountered.
Alteration of the mylonitized dacite is observed both in phenocrysts and matrix. Resulting rock is porous, larger voids incrustated with zeolites, calcite and minor talc. Plagioclases are zeolitized, partly replaced by albite, anortoclase, microcline, and argillized (montmorillonite, illite). A broad set of eleven zeolite species was identified by XRD method: scolecite, laumontite, leonhardtite, stellerite, stilbite (i.e. Ca species) and mesolite, heulandite, Na-stilbite, clinoptilolie, Ca-clinoptilolite (Na-Ca species), and Na-stellerite (Na species). Some of them carry potassium also.
Hornblende phenocrysts turned initially into an alkali amphibole impoverished in iron and titanium releasing them in satellitic grains of magnetite (more seldom titanite or titanomagnetite) which form aureole. Smaller amphibole grains in the matrix and more altered phenocrysts suffered alkali metasomatism. In their place Fe-clinochlore and a set of secondary amphiboles arosed, i.e. tremolite, Na-tremolite, actinolite, edenite, pargasite, K-richterite, Mg-riebeckite, and arfvedsonite. They are intermingled with zeolites, locally calcite, hematite and other opaque minerals.
Pyroxene and mica are dispersed as minor constituents. Pyroxene was determined as acmite-augite, mica as flogopite relics accompanied by vermiculite and mixed layered chlorite/vermiculite, and chlorite/smectite.
Dense intergrowths and heterogeneity of mylonite material make petrographical studies difficult.
At the western contact of mylonitized dacite with roof pendant of Ashua limestones and grey sandstones numerous veinlets of white and colourless transparent zeolites (stilbite, Na-stilbite, scolecite, clinoptilolite, mesolite, heulandite) with calcite and K-feldspars occur. They are irregular, some 1 cm thick. Other, generally thinner veinlets contain calcite, Ca-Na zeolite and green vitrous-acicular actinolite.
Limestone encountered at roof pendant differs. Large fragments at some distance from dacite are bioclastic, containing abundant microfauna and detrital, angular to subrounded quartz grains ca 0,1 mm in diameter. Other fragments, located in the mylonite zone represent grey marble of granoblastic-porphyroblastic texture and stylolite-resembling streaks of reddish matter. The marble contains mosaic of calcite and minor dolomite 0,01-0,02 mm grains, nests and veinlets of crystalline calcite (0,3 mm),

neosomal hipidiomorphic feldspars (0,2-0,5) mm and plates, and radial sheaves of Ca-stilbite or Na-stilbite. The streaks abound in orthoclase and contain some hematite and opaline matter of crystoballite ordering. Brecciated marbles are cut by irregular clinoptilolite-clinochlore veinlets.
Mudstone and finegrained sandstone prevail to the east of the dacite apophysis, i.e. in its floor. They are mostly red, with small white and green nests and streaks. Contain angular grains of quartz and feldspars cemented with clay minerals, locally carbonates or silica. Sedimentological study (Cruz 2002) concluded on continental endoreic lacustrine and alluvial environments.
Near the mylonitized contact with dacite up to a distance of about 1 metre in the red mudstones neosome albite, orthoclase, hematite blasts are present, while in greenish nests tremolite, actinolite, and albite developed. No amphibole knots typical for hornfels were encountered as yet. Red layers contain also clinochlore, vermiculite, talc and swelling chlorite while green fragments contain clinochlore and smectite. Their origin is unclear, must not be related to thermal event. Both varieties of detrital rocks are cut by calcite, gypsum and zeolite veinlets.
The contact aureole in the outcrops described here consists of calcitic contact marbles and chlorite-amphibole slates heavily overprinted by zeolite facies. The mineral assemblage indicates temperatures 300-500°C in the case of amphiboles and 200-300°C in the case of chlorites and 150-250°C for relatively water poor zeolites. Other zeolite species formed probably in still lower temperature interval when pervasive metasomatosis gave way to the circulation and precipitation along fissures. Dacite itself suffered metasomatism leading to alkali amphiboles, chlorite, clay minerals and zeolites. In the Quebrada Rodriguez some dacite pebbles derived from the contact zone contain monticellite veins evidencing relatively high temperature processes.
Zeolite facies metamorphism usually results in the trasfer of low temperature clay minerals into higher temperature polymorphs such as vermiculite. Mineral assemblages include kaolinite and montmorillonite with zeolites, albite, quartz, prehnite, calcite and chlorite.

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