THE CENTRAL ALTERATION BODY OF THE CASAPALCA MINES, PERU

C. J. OVERWEEL

ABSTRACT

The Casapalca mining district in central Peru is a source of lead, zinc, silver and copper ores of the lepothermal type. In the centre of the mine in the shingle zone of the most conspicuous parallel vein system, a body of rock has been intersected that does not fit in the stratigraphical sequence. Various opinions about the origin have been brought forward.

The results of a systematical thin-slide study of the rock type under discussion are in favour of alteration. The coincidence of ore shoots and alteration body with certain structural elements of the Casapalca anticlinorium is discussed.

GEOLOGICAL HISTORY

At an altitude of 4000-5000 metres above sea level, just west of the continental divide along the „carretera central”, which connects Lima with the interior of Peru, the Casapalca mines are situated.

Before the Backus and Johnston Company, later acquired by the Cerro de Pasco Corporation, started with systematic mining in 1888, sporadic mining was done on the high outcrops located east of the steep slope of the Rimac valley. The principal structures run more or less parallel with the Rimac river and dip towards it.

The vein system intersects a broad anticlinorium, the stratigraphical components of which can be taken together in two lithostratigraphical groups; the older sedimentary strata, the „Casapalca group”, are overlain by volcanites.

Both groups are considered to be of Tertiary age. Quaternary and recent deposits here and there cover the Tertiary rocks.

The local subdivisions, based on a lithostratigraphy, as no fossils have ever been found in the Casapalca area, have been worked out by H. E. McKinsty and J. A. Noble (1932), who also did the initial excellent surface mapping of the area. The geological column with subdivisions is shown in Table I.

In the publication of McKinsty and Noble (1932) the strata between the unconformities are taken together under the lithostratigraphical term „formation”. As it is possible, on the basis of field characteristics, to divide the volcanic strata into three distinct units, the author proposes to consider the strata between the unconformities as „groups”, and their first subdivision as „formations” or „members”, depending on the thickness of the stratigraphical units. A more detailed description of the various strata follows:

Machay limestone: This upper part of the Cretaceous strata...
ceous has never been found in the Casapalca district, neither in the outcrops, nor underground during mining operations. **Casapalca Red beds formation**: Alternate calcareous shales and marlite layers up to a known thickness of 1000 metres form the Casapalca Red beds, the lowest formation exposed. A detailed rock description will be discussed further in this article. In between the Casapalca Red beds and Carmen member there are some small lenses of amygdaloid.

**Table 1**

**GEOLOGICAL COLUMN**

<table>
<thead>
<tr>
<th>AGE</th>
<th>EVENT</th>
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<tbody>
<tr>
<td>RECENT</td>
<td>Hot spring deposits</td>
</tr>
<tr>
<td>QUATERNARY</td>
<td>Glacial deposits</td>
</tr>
<tr>
<td>TERTIARY</td>
<td>?</td>
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<tr>
<td></td>
<td>(unconformity)</td>
</tr>
<tr>
<td><strong>Rimac group</strong></td>
<td></td>
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<tr>
<td>Rio Blanco formation: volcanics with intercalated limestone beds</td>
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</tr>
<tr>
<td>Bella Vista formation: limestone and shales interbedded with volcanics</td>
<td></td>
</tr>
<tr>
<td>Carlos Francisco formation: Yauliyacu tuff Carlos Francisco porphyry</td>
<td></td>
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<tr>
<td>Tablachaca volcanics</td>
<td></td>
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<tr>
<td></td>
<td>(unconformity)</td>
</tr>
<tr>
<td><strong>Rio Blanco group</strong></td>
<td></td>
</tr>
<tr>
<td>Carmen member: conglomerate, sandstone, shale and limestone</td>
<td></td>
</tr>
<tr>
<td>Amygdaloidal flows: local</td>
<td></td>
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<tr>
<td>Casapalca Red beds formation (unconformity)</td>
<td></td>
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<tr>
<td><strong>CRETACEOUS</strong></td>
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<tr>
<td>Machay limestone</td>
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</table>

**Carmen member**: The Carmen member is a distinct horizon, its thickness varying from 50 to 300 metres. The combination of conglomerates, limestones and shales is somewhat more resistant against erosion than the Red beds. The resulting effect is that in locations with steep dipping strata the Carmen member protrudes an average of 10 metres above the nearby outcrop of the Casapalca Red beds. **Tablachaca volcanics**: A sequence of andesitic flows and pyroclastics, among which agglomerates tuffs, breccia, and porphyries, include some sandstones, quartzites and limestones. However, the volcanics, especially flows of a purple red porphyry, predominate in this formation which is nearly 800 metres thick. **Carlos Francisco porphyry**: Gradually the Tablachaca volcanics pass into 1-16 metres of andesite porphyry or of porphyry breccia, which consists of angular, usually greenish porphyry fragments in a matrix of reddish porphyry. The predominant colour of the Carlos porphyry is green. Megascopically the porphyries consist of a green or reddish groundmass, in which feldspar laths ranging from 1—4 mm, are evenly distributed. No limestone beds are found among the strata of the Carlos Francisco porphyry which attains a thickness of over 600 metres. **Yauliyacu tuff**: Towards the top of the Carlos Francisco formation the volcanites consist of an alternation of tuffs and solid layers. The red-brown tuff on top has been named Yauliyacu tuff. Because of the slight differences between the Carlos Francisco porphyry and the Yauliyacu tuff, from a lithostratigraphical point of view, and the uncertainty that the individual volcanic beds have a continuous lateral extension, the author has proposed to consider the Yauliyacu tuff as belonging to the Carlos Francisco formation until detailed mapping will reveal the composition of the individual beds (C. J. Overweel, 1956). **Bella Vista formation**: Predominating highly silicious (30 cm to 1 metre thick) limestone layers are interbedded by 1-16 metres thick andesite layers. Magmatic differentiation during a rest period may account for a slightly more
acid nature of the igneous beds of the Bella Vista formation in comparison with the andasites of the Callos Francisco formation. The Bella Vista formation is 150 metres thick.

*Rio Blanco formation:* Between the volcanic strata which are megascopically indentical with the Carlos Francisco porphyry interbedded limestone layers occur. They were formed during volcanic non-activity.

**STRUCTURE**

The average strike of the beds is N.20 W. Figure 2 gives the geological plan after H. E. McKinstry.

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**VEIN SYSTEM**

A parallel group of veins, striking N.35 E. and dipping 70° to north-west, is the most conspicuous feature of the Casapalca system which has been developed across a distance of 3 kilometres in horizontal direction. In vertical direction it has been opened for one kilometre. Strong footwall splits diverge from the principal vein system in a north-easterly direction at angles ranging from 120 to 150 degrees and also dipping to the north-west. Because of parallel junction lines of the parallel veins with the footwall splits, the whole system may be considered as belonging to one fraction pattern. The N.35 E. striking group, at an angle of 34° to the tension direction, are tectic shears belonging to the Casapalca anticlinorium. The footwall splits lie either in the antitetic or in the tension direction (C. J. Overweel, 1957).

a) *Shingles:* Not only in the broad relations of the large veins, but also as a local aspect of the individual veins, parallel structures lie in an echelon or overlapping relation to each other, termed by McKinstry "Shingle-structure" (H. E. McKinstry and J. A. Noble, 1932).

During development to the south, the vein sometimes pinched out. By crosscutting into the footwall a thin, parallel stringer was found which, by continued development, thickened again into a structure of normal width.

During his stay at the Casapalca mines several workings were in shingles and the author had the opportunity to get a clear three dimensional picture of this structure (fig. 3).

In the case of a horizontal section, the name "shingle" is well chosen. However, in a vertical section the "shingle" does not behave like a real shingle. The two horizontally overlapping parts unite further down into a common root.

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Fig. 2 — Geological plan of the Casapalca district after H. E. McKinstry.

An anticlinorium eroded so far that the Red beds and the Carmen-member outcrop, lies in between the syncline of the Americana district to the east and the huge Rio Blanco syncline to the west. The outcrop of both synclines are members of the volcanic series.

The large structural units, described above are made up of several minor folds, as was pointed out by A. R. Still in 1956. Due to the secondary folds, the strata have become thicker than the original undisturbed beds. Asymetrical folds predominate, occasionally they are even overturned. The Casapalca anticlinorium is also asymetrical with its steep, nearly vertical limb to the east.

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Fig. 3 — Three dimensional representation of a shingle.
The best way to visualize a shingle is to tear off a piece of material irregularly and to pull the two parts on both sides of the tear in such a way that they partly overlap.

b) **Mineralization**: The veins average 1 metre in width, ranging from 50 cm to 2 metres. Mineral zoning is notably developed in the main parallel vein system. The mineralization has the characteristics of the lepthothermal class, pyrite, galena, sphalerite, chalcopyrite, tetrahedrite-tennantite and bournonite with a gangue of quartz, calcite and rhodochrosite. This ore fringes out sideways and upwards in respectively, realgar, orpiment, stibnite and argentite, ruby silver, sulphosalts with pyrite in silicious and pyritic gangue. In other words the lepthothermal mineralization is fringed out into a mineralization of a more epithermal character (Geological staff, 1948).

From zonal studies by W. C. Lacy 1947 and G. E. Kruger 1948 we learned that the Carlos Francisco - Aguas Calientes vein system carries three ore shoots. The two outer ones, the Carlos Francisco shoot to the north-east and the Aguas Calientes shoot to the south-west, are parallel to each other with a 50° pitch, the Consuelo shoot is more or less vertical along the plane of the vein. Because chalcopyrite increases downwards along the shoot of the Consuelo section, it has been proposed to classify this ore as low intensity mesothermal (Geological staff, 1948).

**CENTRAL BODY**

The Consuelo section might be considered a large shingle zone between the Carlos Francisco and Aguas Calientes vein; the Carlos Francisco vein is pinching out to the south-west and the Aguas calientes vein is pinching out to the north-east. The Consuelo and Aguas Calientes sections are connected at the 2700 and 3300 levels, which are situated in-between the pinch out vein parts of the San Francisco and Aguas Calientes veins. By these drives a large body of dense, finely grained, light gray rock was intersected with disseminated minute pyrite cubes and epidote nodules of several cm. in diameter.

F. E. McKinstry and J. A. Noble (1932) thought of an alteration body. The author agreed with this assumption (1955, 1957). However, because of only megascopical investigation and the possibility of an upthrust of lower strata, the assumption was also brought forward that the body which did not fit in the normal stratigraphical sequence could be Machay limestone (A.R. Still 1956).

The difference of opinion about the character of the central body and the interesting geological aspect of this zone, where high temperatures and hot water prevail, prompted a systematic thin slide investigation of the area under discussion. J. W. Lavin, superintendent of the Casapalca Mines, and the staff of the geological department of the Cerro de Pasco Corporation, in particular A. F. C. Meyer, resident geologist in charge of the geological department of the Casapalca Mines and geologist I. M. Iberico, were so kind as to furnish us with a set of samples taken along the 2700 level.

**THIN SLIDE INVESTIGATION**

*Casapalca Red beds*: Megascopically, the Red beds are compact, very fine grained, rocks that effervesce in hydrochloric acid. They are laminated with a thickness of $\frac{1}{2}$ mm or more; compact banks up to 1 metre thick are intercalated in between the finer laminated beds. On the surface a pale red to grayish red colour predominates (5R 6/2-5R 4/2). However, beds with a greenish-gray hue also occur.

Microscopically, we learn that very finely-grained calcite with a grain size range of 0.02 to 0.16 mm, and patches of chloritic matter, with a diameter of 0.1 to 0.2 mm, form a tight matrix with a faintly parallel direction, in which angular quartz grains (grain size 0.1—0.2 mm) are evenly scattered (fig. 4).

The proportion of calcite to chlorite varies from 0.24 to 11.43, while the quartz content remains fairly constant at an average of 12%. This is illustrated in the triangle diagram, fig. 5, where the points of the light essentials of the Red beds lie more or less in one line parallel to the chlorite calcite side.

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![Fig. 5 — Composition diagram of the Red beds.](image)

- O redbrown coloured samples
- • grey green coloured samples
- ★ average composition projected on quartz calcite line

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2 Rock colour chart „The Geological Society of America“ 1951.
The calcite mainly occurs as finely grained aggregates intermingled with chlorite material, but occasionally clearly crystalline calcite is also found. The chlorite is very pale green, almost colourless, and faintly pleochroic in tones of pale green and colourless. The birefringence ranges from 0.004 to 0.008.

As is obvious from fig. 5, the composition of the light components does not influence the colour of the red beds. Haematite, disseminated and in grains with a size range of 0.01—0.1 mm, is responsible for the red colour. The disseminated haematite is encountered in the calcite grains as well as in the chloritic material. The grey green colour is found with the samples in which haematite is altered into limonite or goethite.

According to the nomenclature of F. J. Pettijohn 1956, the Red beds can be classified as calcareous shales and marlites; these terms refer to the laminated components and the compact banks respectively.
The central body: General megascopical description. In the centre of the mine where Red beds should be expected a megascopically fine grained compact yellowish gray rock (SY 8/1). is found. The texture has no direction and pyrite cubes up to \( \frac{1}{2} \) mm are evenly distributed. Epidote nodules 4—5 cm in diameter are met with. Pyrite cubes are practically not found here. The samples of the central body vary in their mineralogical composition. A microscopical interpretation of the various constituents follows below.

a. yellowish-gray rock: In a matrix of zeolites, (grain size ranging from 0.02 to 0.9 mm), pyrite cubes (grain size 0.1—0.7 mm), irregular calcite grains (grain size 0.03—0.07 mm) and epidote flakes averaging 0.02 mm are scattered. (Fig. 6).

The refringence of the zeolites varies from 1.505 to 1.528. The birefringence is ± 0.003 and the optical sign is uniaxial negative for most grains. Some biaxial positive grains with + 2V = ± 50 occur.

According to the "Bestimmungs Tabellen" of W.E. Tröger, 1956, a chabasite occurs in the refringence range mentioned above. The rhombic section occasionally seen in this slide also speaks for chabasite.

b. epidote nodules: Regularly distributed angular quartz grains (ranging from 0.2 to 0.14 mm), chalcedonic aggregates with rounded forms and calcite in crystallized grains of irregular shape (grain size 0.1 to 0.2 mm), form the microscopic texture of the epidote nodules (fig. 7).

The nodules consist of 58% quartz and chalcedony, 22% calcite and 20% epidote. The quartz grains are in the same size range as those of the Red beds and also occur in about the same quantity.

The epidote grains are irregular with an average of 0.05 mm, their birefringence amounts to 0.050 and the optical angle varies, as is common in the epidote group.

It is remarkable that zeolites do not occur in the nodules. The presence of quartz, which has not been proved in the zeolite rich part especially as regards the form and quantity in which it occurs, suggests that the epidote nodules could be considered relics of the original Red beds.

c. Yellowish-gray rock containing veinlet: Another sample of the yellowish-gray rock contained a 3 mm wide pyrite, sphalerite veinlet. A thin slide close to the vein was made to get a better understanding of the wall rock alteration caused by that small structure. Quartz grains in the size range of 0.1 to 0.3 mm intermingled with zeolites form a compact mass in which pyrite, sphalerite and calcite grains are scattered. Some chlorite and epidote, 2 and 1% respectively of the total volume, occur. There are zeolite rich areas and quartz rich areas. The calcite is restricted to the zeolite-rich parts. The quartz that covers 30 volume % is bigger than the quartz grains in the Red beds. Moreover it is somewhat subhedral.

The 30 volume % zeolite grains are diamond shaped in section and they contain 0.01 mm large inclusions in clusters. The inclusions could be determined as calcite epidote and chlorite. The grain size of the large zeolites varies from 0.04 to 0.2 mm. Optical properties: uniaxial negative, birefringence 0.003; the refringence varies from 1.505 to 1.528. W.E. Tröger, 1956, gives a chabasite with the properties just mentioned in his Schüssel diagram.

21% Pyrite occurs in cubes, 9% sphalerite in crystalline aggregates and 7% calcite is found in distinct crystalline grains. The sphalerite contains chalcopyrite blebs, sphalerite and pyrite form clusters:

d. Samples taken on the periphery: Towards the periphery the yellowish-gray rock changes very gradually into the Red beds to the south-west and the Carmen member to the north-east.

Two samples of the set investigated came from the periphery, one near Aguas Calientes and the other close to the northern part of the Casapalca mines. Megascopically these two samples look slightly different in comparison with the bulk of the central body. The colour is light olive-gray and the fresh surface has somewhat more lustre than the dull chalky aspect of the yellowish gray rock. The fracture is also conchoidal. The general aspect is tighter than the yellowish gray rock.

Microscopically they consist chiefly of chalcedony in which evenly distributed, splintered quartz grains and calcite aggregates, small percentages of chlorite, sericite and pyrite occur (Fig. 9).

Synopsis of the thin slide investigation: The various constituents of the rocks described are represented at the corners of a tetrahedron in the following way (Fig. 10).

Quartz, chlorite and calcite, the light components of the Red beds, are marked down at the corners of the base. The new minerals encountered in the central body, the zeolites and epidote, are placed together at the top of the tetrahedron.

The base which forms the triangle of the Red beds has already been discussed (fig. 5). To represent the average composition of the Red beds on the lateral plane of the tetrahedron,
which has zeolites, epidote, quartz, and calcite at its corners, the position of the composition of the various samples parallel to the chlorite-calcite line could be used. Fig. 11 shows a composition triangle with zeolites, epidote at the top, quartz, chlorite, and calcite at the base corners. The average composition of the Red beds is indicated by a star at the base line.

In the samples of the central body the much higher quartz content, mainly as chalcedony, is striking. Towards the periphery of the central body only a higher chalcedony content distinguishes the rock under discussion from the Red beds, but towards the centre new minerals, zeolites in particular, and epidotes, are added to the original mineralogical constituents of the Red beds.

The composition of the epidote nodule is close to the periphery samples on the base line, which agrees with the suggestion that the epidote nodules could be considered relics of the original Red beds, as was stated above.
The way in which the composition of the investigated samples of the central body passes into the common sedimentary strata from the centre towards the periphery, together with the fact that the new minerals encountered are chalcedony and epidote, speaks strongly for hydrothermal alteration. Field evidence for alteration are the gradual contacts, the spindle-shape, the non-continuance along the regional strike and the ore shoot enclosed in this body. The name "central alteration body" will be used further in this article.

High temperatures and hot water originate in the central alteration body. The zeolites, especially chabasite as a hot spring deposit, suggest that the hot water may be partly juvenile.

THE INFLUENCE OF STRUCTURE ON THE LOCATION OF ORE SHOOTS AND CENTRAAL ALTERATION BODY

In order to understand why in the central part of the mine such a strong alteration zone has been formed one has to reconsider the ore shoots and zoning of the Casapalca parallel veins. Fig. 12 has been taken from a publication by the geological staff of the corporation (1948).

The copper distribution gives a general idea of the location of the ore shoots; two of them, the Carlos Francisco shoot and the Aguas Calientes shoot, run more or less parallel; the Consuelo ore shoot in the centre has a vertical position along the plane of the veins.

In the article of the geological staff (1948) it is stated that the chemistry of the wall rock does not exert a significant control on the grade of ore deposited within it. Because the various rocks responded more or less individually to the stresses that produced the fractures there is some degree of correlation between kind of rock and abundance of ore through the influence of structure.

The parallelism of the Carlos Francisco and Aguas Calientes shoots, however, suggests an even more important role of the structure. With the data we have at Leiden the structure of the Casapalca anticlinorium has been reconstructed and compared with the mineralization zones of figure 12. The coincidence of the ore shoots

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Fig. 9 — Periphery of central body. 2700 level at 3005 Carlos Francisco coordinate. Crossed nicols, 100 x. In a matrix of chalcedony, splintery quartz grains and calcite aggregates are evenly distributed.

Fig. 10 — Composition tetrahedron.
Fig. 11 — Composition diagram of the samples taken in the central alteration body.

av.r. = average composition Red beds
E.n. = epidote nodule
E.p. = epidote poor part of yellowish grey rock
S = yellowish grey rock sample containing veinlet
P = samples taken on the periphery of the central alteration body

Fig. 12 — Longitudinal section of Casapalca vein showing distribution of copper and distribution of rocks and zoning of mineralization.

Zone 1 — Low copper and silver, moderate lead and zinc, intense silification, rare sericite and carbonate, arseno-pyrite, hubnerite, galena, sphalerite and pyrite cubes.

Zone 2 — High copper, silver, lead and zinc, mild silification, abundant manganiferous carbonate and sericite, tetrahedrite, galena, sphalerite and pyrite cubes and pyritohedrons.

Zone 2A — High copper and zinc, low silver and lead, moderate silification, common manganiferous carbonate and sericite, chalcopyrite, sphalerite, tetrahedrite, galena and pyrite cubes, and pyritohedrons.

Zone 3 — Moderate silver, lead and zinc, low copper, weak silification, abundant manganiferous carbonate and sericite, bournonite, geocronite, stibnite, tetrahedrite sphalerite, galena and pyrite pyritohedrons.

(geological staff corporation 1948, p. 31).

Fig. 13 — Longitudinal section of the Casapalca vein showing how the ore shoots coincide with the axial planes and the steep limb of the Casapalca anticlinorium.

with certain structural elements is striking (fig. 13).

Zone 2A, in the Consuelo section, coincides with the steep limb of the anticlinorium, while zone 2, containing the ore shoots of the Carlos Francisco and Aguas Calientes sections, concurs with the intersection of the vein system and axial plane. The vertical position of zone 2A, in contrast to the 50° parallel running pitches of the ore shoot of zone 2, is now much better understood.

The structure of the fold seems to have played an important part in the location and the spatial position of the ore shoots in the tectic shears of the Casapalca anticlinorium.

The fact that the central alteration body around the "hottest" ore shoot in the lime-rich Red beds is located in the steep limb of the anticlinorium, where movement and crumbling of the calcareous shales during the folding must have been relatively stronger than in the flat elements of the folds, is also in agreement with the conception, that the intersections of the weaker structural elements with the tectonic shears served as the primary paths of the mineralizing solutions, which formed the deposits of the strong parallel structures opened in the Casapalca mines.

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