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Mineral Deposits at the Beginning of the 21st Century

Edited by

Adam Piestrzyński et al
Faculty of Geology, Geophysics and Environmental Protection
University of Mining and Metallurgy, Kraków, Poland

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Cover photograph: Marcasite from the MVT deposits, Pomorzany Mine, S-Poland
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The hydrothermal sinter and kaolinite-Au-Ag occurrences of Ixtacamaxtitlán (Puebla, Mexico): preliminary results

A. Camprubí & J. Tritlla
Unidad de Investigación en Ciencias de la Tierra, UNAM, Campus Juriquilla, Querétaro, Mexico

R. Corona-Esquivel & E. Centeno
Departamento de Geoquímica, Instituto de Geologia, UNAM., México D.F., Mexico

A. Terrazas
Luismin S.A. de C.V., México D.F., Mexico

ABSTRACT: The hydrothermal deposits of the Ixtacamaxtitlán area are hosted by volcanic and intrusive rocks of the Mexican Ignimbritic belt. These deposits show quartz-chalcedony-sulfide banded veins and stockworks, kaolinite formation, and silica caps on top, interpreted as hydrothermal sinter. The occurrence of kaolinite is due to acid-sulfate alteration, possibly derived from boiling at shallow depths. The alteration assemblage ranges from clorite-sericite to acid-sulfate from the deepest parts. The characteristics of the ensemble, plus the geochemical anomalies in Au and Ag in the stockworks, may indicate the presence of economic mineralisation at depth. The deposits are interpreted as hot spring-type low-sulphidation epithermal deposits.

1 INTRODUCTION

1.1 *Location*

The study area is located in the Ixtacamaxtitlán municipality, in the northern half of the Puebla state in Central Mexico, close to the border with the Tlaxcala state (Fig. 1). The geological setting of the study area is defined by the junction of three major physiographic provinces: the limestone formations of Eastern Sierra Madre (ESM), the extrusive and intrusive felsic rocks of Western Sierra Madre (Mexican Ignimbritic Belt, or MIB), and the mafic volcanic rocks of the Trans-Mexican Volcanic Belt (TMVB). Little research on economic geology has been carried out in this zone, and only technical information on exploration for kaolin, issued by the *Consejo de Recursos Minerales* (Mexican Council for Mineral Resources), is available. Similar deposits, that were formerly exploited for kaolin, were reported by González-Reyna (1956), in Chignahuapan and Coayuca, close to Ixtacamaxtitlán, and may define a prospective area. An earlier report on the study area has been published by Camprubí et al. (2000). This area is presently under exploration by the Luismin Mining Company.

1.2 *Geological setting*

The geology of the area (Fig. 1) is represented by (1) Cretaceous limestone formations, corresponding to the ESM, and (2) igneous intrusive and extrusive rocks of Tertiary to recent age. The carbonates from the ESM present in the area (Reyes-Cortés 1979) correspond to the Lower and Upper Tamaulipas Formations (Lower and Middle Cretaceous, respectively) and the Agua Nueva Formation (Upper Cretaceous). The latter formation is exposed in the studied deposits, and consists of grey limestone, layered thin to medium-size, with interbedded silex lenses and nodules.The whole limestone sequence was affected partly by the Laramide Orogeny (in this area, during the Turonian-Maastrichtian).

The Agua Nueva Formation is discordantly overlain by Tertiary rhyolitic tuffs (undetermined in age) corresponding to the MIB. The rhyolitic tuffs are mainly of pyroclastic origin, with phaneritic textures. Also associated with the magmatic activity of the MIB, there is an assemblage of plutonic to subvolcanic rocks which intruded the above assemblage. This intrusive event produced mainly diorite to porphyry granite with textures ranging from porphyric to aphanitic. At the contact between Cretaceous limestone and the intrusive rocks, hornfels and skarn of small volume were formed. The rhyolitic tuffs and the intrusive rocks were affected by hydrothermal alteration. The outcropping hydrothermal alteration assemblages consist of strong kaolinitisation and silicification of igneous rocks, with some chlorite in the lower parts.

It is thought that the hydrothermal deposits, whose age is still undetermined, formed between Oligocene and Miocene. Finally, TMVB basalt and andesite were deposited, from late Miocene to present. All these materials are covered by recent alluvium and hillside deposits and, also, by a brown fine-grained cover that is found widespread in all the region, completely overlaying the topography. The mineralogy of this cover, although weathered, con-

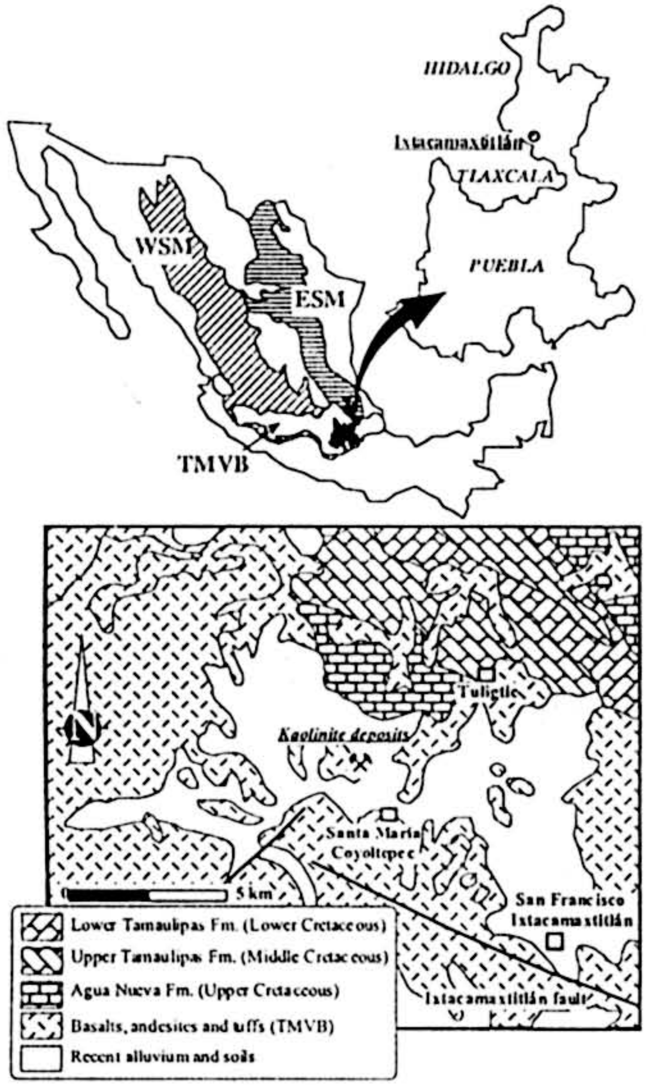

Fig. 1. Geographical and general geological setting of the hydrothermal deposits of Ixtacamaxtitlán.

sists of magnetite, apatite and pyroxene in stream sediments. Thus, according to this mineralogy and its disposition, we interpret this unit as formed by a recent ash-fall, probably caused by the eruption of major volcanic centres nearby, as the Citlaltépetl (also known as Pico de Orizaba) or Malintzi (or Malinche) volcanos. The present research is focused on the hydrothermal deposits, hosted by MIB igneous rocks, which are described from bottom to top, as follows.

2 HYDROTHERMAL DEPOSITS

2.1 *Veins*

Subvertical veins of quartz, chalcedony and subordinate base-metal sulfides (mainly pyrite), up to 1-1.5 metres thick, are found crosscutting a quartz porphyritic subvolcanic body. The internal structure of these veins is mostly banded, containing also cockade structures and idiomorphic quartz-lined vugs, and are seldom massive. Preliminary chemical essays done by Luismin S.A. de C.V. on 15 samples of this unit determined up to 0.2 ppm Au.

2.2 *Stockwork*

This unit occurs in the upper part of the outcropping veins, coupled with them as satellite veinlets and forms arrays of millimetre- to centimetre-size veinlets (Fig. 2) separate from the main veins. The veinlets consist of quartz and pyrite, with minor quantities of chalcopyrite and sphalerite. The stockwork occurs on the top of the veins and also parallel to them. This unit may be up to 5 metres thick, as observed in stream outcrops. Preliminary essays done by Luismin S.A. de C.V. on 20 samples of this unit determined up to 0.8 ppm Au.

2.3 *Kaolinisation and silicification*

This is not a 'separate' unit, as it occurs coupled with veins and stockworks, but the intensity of alteration increases upwards, ranging from the partial replacement of feldspar phenocrysts of the intrusive assemblage to the obliteration of the textures and most alteration assemblage forms kaolinite bodies of up to 50 metres in thickness.

2.4 *Silica caps*

This unit mostly consists of thin layers (millimetre to centimetre-thick; Fig. 3) of amorphous silica (opal), occasionally interbedded with kaolin pods and clays. Some layers display structures that strongly suggest that this deposit formed in a subaerial environment; such structures are bioturbation,

Fig. 2. Image of centimetre-size quartz (white) veinlets of the stockwork unit, with base-metal sulfides in the centre (dark), hosted by altered granitic porphyry, with sericite and chlorite as alteration minerals. Length of base of photograph is about 1m.

Fig. 3. Layering of opal in a block from the silica cap. On the left side massive opal is shown, and the common centimetre-size layering is shown on the right. Bottom to top of deposition goes from left to right.

the presence of imprints of vegetal remains —such as roots, branches, etc.— and, above all, the presence of mud cracks in the opal layers (Fig. 4). The latter is the most characteristic sedimentary structure of the deposit.

The above sedimentary structures indicate that deposition of the amorphous silica occurred in a hot spring pool, and that this was controlled by climate stationality, provoking alternate periods of hydro-

Fig. 4. Mud-crack structures in opal from the silica cap.

Fig. 5. View of the main outcrop of opal layers (upper part of the picture, darker) and of the kaolinite unit (light colour). The

thermal activity and lull inpaucity that led to subaqueous deposition of silica and the subsequent desecation with some regularity. This unit is also

cutting the main kaolinite bodies, up to few centimetres thick. Such veinlets are thought to have been the feeder channels of the hydrothermal solutions on their way to the paleosurface. Other structures found in the silica caps are opal ooliths, that are interpreted as having formed due to wave activity in the hydrothermal pool. The base of this unit hosts a layer, up to 2 metres thick, of breccias with fragments of host rocks, cemented by opal or quartz crystals. This breccia is interpreted to have formed by local violent upwelling of hydrothermal fluids.

The whole layered opal deposit, partly eroded, sizes up to 10 metres vertically (Fig. 5). The characteristics of the silica caps of this area suggest that this is a fossile sinter-type deposit, formed in a hot spring environment. Silica caps and the kaolinized units are found in two outcrops at different elevations; it is not clear whether they formed originally at different elevations or whether there is a recent fault between, covered by the ash-fall cover and hillside deposits.

3 MINERAL EXPLORATION

During the period when the kaolinite deposits of Ixtacamaxtitlán were a fund by the *Consejo de Recursos Minerales*, a drilling program, coupled with some underground and open pit mining was carried out to determine the kaolin reserves of the area (Fig. 6). These studies indicated an average thickness for the kaolinite bodies of about 30 metres, with more than 2 million tons reserves. The physical essays done by the *Consejo de Recursos Minerales* on kao-

Fig. 6. General view of the main outcrop of the silica cap (dark top of the hill) on top of the kaolinite unit, showing a small open pit at the contact between the silica cap and the kaolinite unit.

linite samples characterised these as being of the sandy-siliceous type. However, kaolinite is not the only object of economical or geological interest in the area, as its occurrence with that of other hydrothermal formations altogether allow to interpret the presence of an important paleo-hydrothermal system in this area. Recently, Luismin Mining Company some detected Au and Ag anomalies in the stockwork below the silica cap and the kaolinite unit.

4 DISCUSSION AND CONCLUSIONS

Although the occurrence of kaolinization of rocks close to a paleo-surface is a common characteristic of high-sulphidation epithermal deposits, this hydrothermal alteration may also be associated with the formation of a hydrothermal system of low-sulphidation type (White & Hedenquist 1990), derived from boiling of hydrothermal fluids at depth. Boiling at depth may cause cooling and an increase in pH of the remaining saline solutions and a vapor loss that migrates towards the surface, containing gas species as H_2S, HCl, and CO_2. These gases condensate in the surface, near the surface or at the phreatic

teration assemblages in low-sulphidation epithermal deposits is commonly associated with steam-heated acid phreatic waters close to surface —without economic mineralization— or, otherwise, may be a late superimposition.

The presence of geochemical anomalies of Au and Ag in stockworks of the Ixtacamaxtitlán area, plus the characteristics of the other hydrothermal formations, as (1) banded quartz and chalcedony veins with base-metal sulfides, (2) the gradation of hydrothermal alteration from chloritic to acid-sulfate from bottom to top, (3) the structure of the deposit grading from veins, to stockwork, and a silica cap from bottom to top, and (4) the occurrence of hydrothermal sinter on top of the deposit, may indicate the presence of an Au-Ag low-sulphidation epithermal deposit at depth with potentially economic importance. These characteristics fit the model of close-to-pluton low-sulphidation epithermal deposits or the shallow boling 'hot spring type' after Albinson et al. (2001), similar to the deposits of Sulfur, Nevada, and McLaughlin, California (Sherlock et al. 1995).

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