ANDALUSITE HORNFELS

PO1

By Z.D. Hora

IDENTIFICATION

SYNONYM: Chiastolite hornfels.

COMMODITIES (BY PRODUCTS): Andalusite (staurolite, garnet).

EXAMPLES [BRITISH COLUMBIA (MINFILE #) - *Canada/International*]: Kootenay (082FSE099), Kwoiek Needle (092ISW052), Atna Peak (103H040); *Kiglapait (Labrador, Canada), Canso (Nova Scotia, Canada), McGerrigle Pluton (Quebec, Canada), Groot Marico-Zeerust, Thamazimbi, Lydenburg (Tranvsaal, South Africa), Glomel (France), Tomduff (Ireland), Spargoville (Western Australia), Aktash (Uzbekistan).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Andalusite occurs in metamorphosed rocks of originally clay-rich composition (usually pelitic) in thermal aureoles formed in the proximity of igneous intrusions. Andalusite is formed under conditions of high temperature and low pressure.

TECTONIC SETTINGS: Mostly in orogenic belts, but also may occur in a platformal environment. Orogenic plutonism intruding pelitic sedimentary sequence.

DEPOSITIONAL ENVIRONMENT/GEOLOGICAL SETTING: Andalusite hornfels is a product of thermal recrystallization of rocks with high alumina and low calcium contents. The protolith is usually argillaceous sediment, but may also be hydrothermally altered volcanic or volcaniclastic rock. The whole spectrum of granitic to gabbroic igneous rocks can act as a source of heat may cover the whole spectrum from granitic to gabbroic composition. Metamorphic zonation of the contact aureole is characterized by distinct mineral assemblages and textural features, where andalusite may be major or minor component, fine grained or as crystal porphyroblasts several millimetres or even centimetres in size.

AGE OF MINERALIZATION: Precambrian to Tertiary. The largest producing deposits are related to intrusion of the Bushveld Igneous Complex (South Africa) about 1.95 billion years old. The deposit in France, the second largest producer in the world is related to granite of Hercynian age. The occurrences in British Columbia are Cretaceous and Eocene in age.

HOST/ASSOCIATED ROCK TYPES: The host rocks are chiastolite metapelite. The associated rocks are spotted slates, andalusite-cordierite hornfels, staurolite hornfels, spinel-corundum hornfels, silimanite hornfels, skarns and a variety of igneous intrusions.

DEPOSIT FORM: Large intrusions into pelitic sedimentary units may produce tabular deposits 20 to 60 metres wide and up to 6 kilometres long. Majority of occurrences are small and irregular in shape. Primary deposits may be associated with alluvial and eluvial accumulations.

TEXTURE/STRUCTURE: Andalusite forms euhedral crystals as porphyroblasts in a fine grained matrix. Individual crystals may reach the size of 60 millimetres in length. Randomly oriented minerals are characteristic of decussate texture. The chiastolitic rocks are characterized by fairly homogenous distribution and size of the andalusite crystals.

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ORE MINERALOGY: (Principle and *subordinate*): Andalusite, *staurolite, garnet.*

GANGUE MINERALOGY (Principle and *subordinate*): Fine grained hornfels matrix - usually cordierite, biotite, muscovite, chlorite and quartz.

ALTERATION MINERALOGY: Retrograde metamorphism results in andalusite being altered to mica and staurolite or mica and chlorite. Such alteration (even partial) may render the andalusite unusable for industrial applications.

WEATHERING: Andalusite is not highly susceptible to chemical weathering and as such, may accumulate in alluvial sediments or as a residual deposit.

ORE CONTROLS: Andalusite development is a factor of the composition of the protolith and the high temperature/low pressure conditions adjacent to an igneous intrusion. The chemical nature and thickness of the original sedimentary layers and their respective distance from the intrusive contact are the main controls on the formation of andalusite hornfels orebodies. Although the metamorphic aureole may extend a large distance, typically only a few areas within the aureole satisfy the conditions necessary to produce economic accumulations of andalusite.

GENETIC MODELS: Andalusite deposits develop in pelitic rocks with high alumina and low calcium contents at temperatures of 550° to 600°C and low pressures of about two kilobars. Such conditions usually develop within the contact aureole of an intrusive. At higher temperatures, sillimanite or corundum and spinel would form at the expense of andalusite.

ASSOCIATED DEPOSIT TYPES: Wollastonite (K09) and garnet (K08) skarns form under similar circumstances from calcium-rich protoliths. Andalusite hornfels deposits can be the source for placer andalusite (C01, C02). Microcrystalline graphite (P03) and gem corundum (Q09) are also found in contact aureoles of igneous rocks.

COMMENTS: Under special conditions, regional, low pressure metamorphism can result in crystallization of sufficient andalusite to be a commercial grade. Some contact aureoles of large intrusive complexes, like the Bushveld Complex, are so extensive that they have features similar to regional low-pressure metamorphism.

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: None.

GEOPHYSICAL SIGNATURE: None.

OTHER EXPLORATION GUIDES: Andalusite, corundum and spinel in alluvial deposits; geological contacts of pelitic sediments with plutonic rocks; sedimentary roof pendants in large plutonic complexes. Most deposits are found within one km of the related igneous intrusion. Economic deposits are more likely in prospective regions with well developed weathering profiles.

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ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: . South African deposits contain approximately 35 Mt of economically recoverable reserves. The Andafrax deposit is a 60 m thick zone with 5 to 20% andalusite crystals and with production of about 36 ktpy. The Grootfontein mine contains 15% andalusite with annual production capacity estimated at 140 kt. The Krugerspost deposit has an average width of 20 m with andalusite content 8 to 12% and annual mine production about 30 kt. The Havercroft mine has a 50 m thick hornfels ore zone with 7 to 8% andalusite and annual mine capacity about 50 kt. The Hoogenoeg mine ore contains between 8 and 12% andalusite; production capacity is 35 kt per year. The Kerphales deposit in France contains 15% andalusite crystals and is about 400 m thick. It has proven and possible reserves of 10 Mt and produces 65 kt per year.

ECONOMIC LIMITATIONS: Andalusite concentrate should contain from 57 to 61% Al_2O_3 and 0.6 to 0.9% Fe_2O_3 and is priced between US$180 and US$140 per tonne (Industrial Minerals, 1997). Because of extreme hardness, some fresh andalusite hornfels are uneconomic to process in spite of high andalusite content and only the weathered zones are mined (Hoogenoeg mine, South Africa). Andalusite recovery generally ranges from 50 to 60%, some production from primary deposits is supplemented from adjacent alluvial accumulations.

END USES: The most important use of andalusite is in monolithic refractories and unfired bricks for blast and glass furnaces, cement kilns and combustion chambers. Smaller quantities are used in specialty ceramics, like spark plugs, acoustic tiles, etc.

IMPORTANCE: Andalusite is a high quality, raw material for high-alumina refractory products. It can be substituted by synthetic mullite, kyanite and sillimanite.

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