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Petrography and the Texture of the Karoo Basalts in Zambia

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Abstract: The Karoo basins of south-central Africa evolved during the first-order cycle of supercontinent assembly and breakup of Pangea, under the influence of two distinct tectonic regimes sourced from the southern and northern margins of Gondwana.

The **Batoka Formation** is a geological formation in the Zambezi valley in Botswana, Zambia and Zimbabwe. It is predominantly a volcanic unit comprising mainly basalts.It was formerly thought to contain sand stones containing the dinosaur *Vulcan Odon*

Outpourings of basaltic flows in the early Jurassic terminated Karoo deposition. The basic volcanic rocks of the Batoka Basalt Formation crop out extensively to the south and southwest. The formation has an estimated thickness of over 400m and is made up of separate basaltic to andesitic flows from 3 to over 30 m thick with vesicular upper surfaces. Agglomeratic intercalations up to 7m thick are present locally, near the top of the sequence.

The basalt dips at a lower angle than the underlying sandstones and the contact may be uncomfortable. On fresh surfaces, the basalt is generally black or partly greenish to dark grayish-green and reddish-purple. It weathers to a reddish-brown clay and contains abundant calcareous concretions and agates. Pyroclastic units containing 'bombs' of vesicular and more massive lava in a fine-grained brownish, glassy matrix containing abundant zeolites. The basalt is composed mainly of individual or clustered phenocrysts of feldspar (labradorite-andesine) set in a groundmass of unoriented plagioclase laths, augite, subhedral grains of magnetite and small amounts of acicular apatite and aggregates of serpentine pseudomorphing olivine. Scolecite, mesolite(and agate occupy fractures and amygdules. In general, the basalt is tholeiitic. **Scolecite** is a tectosilicatemineral belonging to the zeolite group; it is a hydrated calciumsilicate, $CaAl_2Si_3O_{10}\cdot 3H_2O$

Introduction

Basalt is a dark-coloured, fine-grained, igneous rock composed mainly of plagioclase and pyroxene minerals. It most commonly forms as an extrusive rock, such as a lava flow, but can also form in small intrusive bodies, such as an igneous dike or a thin sill. It has a composition similar to gabbro. The difference between basalt and gabbro is that basalt is a fine-grained rock while gabbro is a coarse-grained rock.

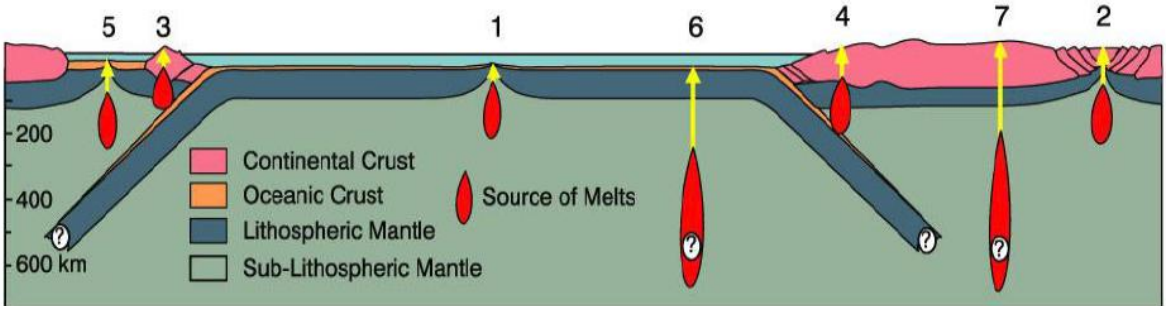


Figure 1: Basalt classification based on tectonic setting

1. Mid-ocean ridge (divergent margin): thin crust, asthenosphere is close to earth'ssurface, mantle upwelling, abundant basaltic volcanism/plutonism, e.g. Juan de FucaRidge, East Pacific Rise, Mid-Atlantic ridge.
2. Intraplate volcanic/plutonic rift system, e.g. East African rift, Rio Grande rift.
3. Island arc (convergent margin): built largely on oceanic crust—composed largely ofisland arc basalt and andesite.
4. Continental arc (convergent margin): formation of new crust, volcanism/plutonism,mountain building, regional metamorphism.
5. Back arc basin: basaltic volcanism—similar to MORB.
6. Ocean islands: basaltic volcanism, e.g., Hawaii, Canaries, and many others.
7. Scattered intracontinental activity: may be continental hotspots, e.g.,Yellowstone

Basalts can be subdivided into:

I: **Oceanic**

(a) Midoceanic Ridges

(b) Oceanic Islands:

Both tholeitic and alkali basalt suite are present

II: **Continental**

This can be subdivided into:

(a)Ophiolites

(b) Plateau / flood basalts

(c)Basalt in Rift zones

Geology of Karoo Basalt

Widespread subsurface occurrences of Karoo basalts are present along the eastern margin of the Barotse basin trending north-northwest in western Zambia and in adjacent parts of Angola. To the south these basalts are continuous with the basalts underlying neighboring parts of Namibia and Botswana and with the Batoka basalts traversed by the Zambezi River gorges east of Victoria Falls. The Barotse basin is a half graben with a step fault zone at its eastern margin that follows a line offsetting structural and geophysical trends in the Pan-African Damaran-Lufilian mobile belt. Faulting and basalt effusions occurred along a zone of structural weakness that possibly represents a Pan-African transcurrent fault. Trends of basalt occurrences in eastern Namibia, northern Botswana, and southern Zambia also follow Pan-African dislocation zones. Karoo volcanism in the center of the African plate is closely related to pre-existing lines of structural weakness associated with the Pan-African tectonothermal event.

Several hundred meters of lavas overlie reddish grit and sandstones. The number of flows cannot be determined accurately. There are six flows at Dombwe hill (south of Kafue – Chirundu road), but exposures in rivers suggest thatmany are present.

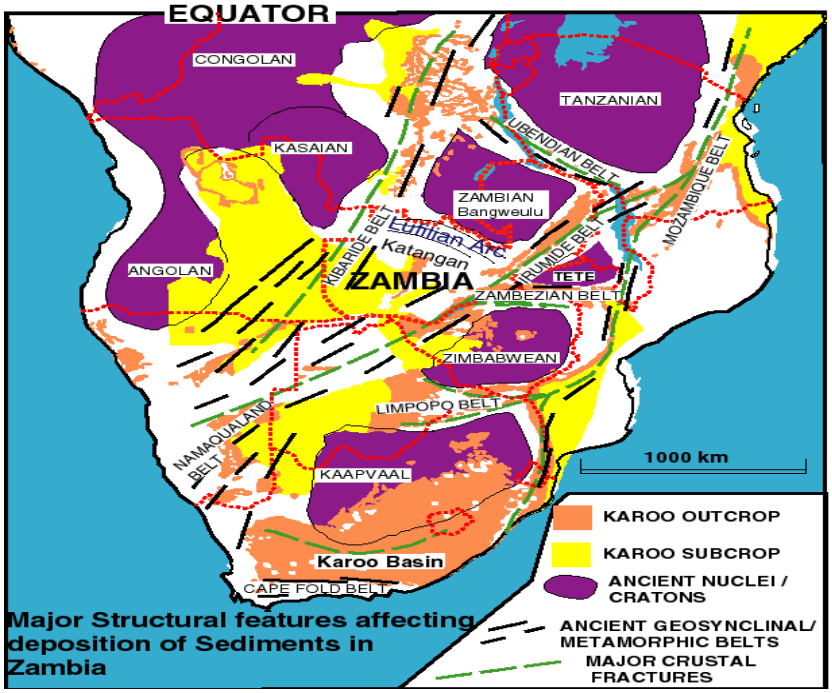


Figure 2: Regional geological setting of Zambia (modified after Porada, 1989)

Each extrusion produced a single lava flow. Because basaltic magma has a very high temperature (about 1,000ºC ± 200ºC) and low viscosity, a single flow will extend over a great distance from the fracture before it cools and crystallizes to form the rock Basalt. As a result of this fact and because enormous volumes of magma were extruded during the Karoo period, the basalt buried large areas of the continental surface.

The *Tectonic setting of the Karroo Super group in Zambia (Nyambe 1993)*estimates that the total thickness is about 650 feet. The basalt is in sharp and contact with sandstone and faulted with schist and quartzite.

The oldest geological formation in the Victoria Falls area is the Karoo-age (~180 Ma) Batoka basalt. The basalt is well exposed in the gorges below Victoria Falls, where it forms a series of steep near-vertical bare cliffs with, poorly developed vertical columnar jointing.

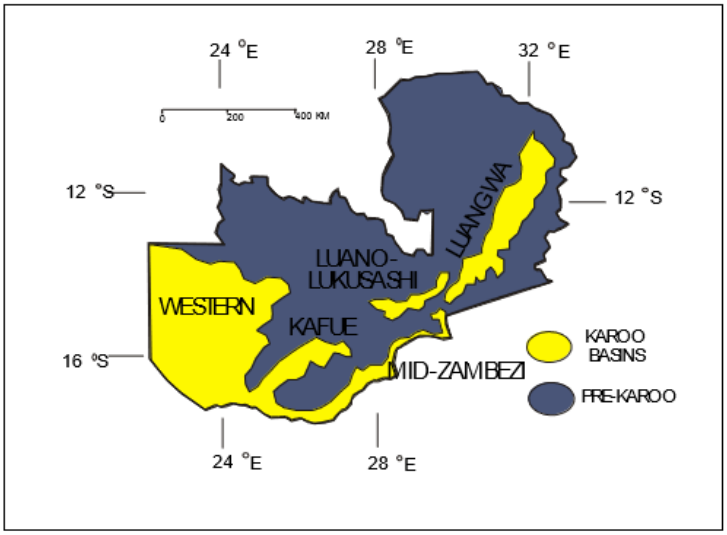


Figure 3: Tectonic setting of the Karroo Super group in Zambia (after Nyambe, 1993)

Mode of occurrence

Batoka basalt flows at Siyakobvu(Siavonga District, Southern Province)

Basalt flows exposure at the Victoria Falls(Livingstone District, Southern Province)

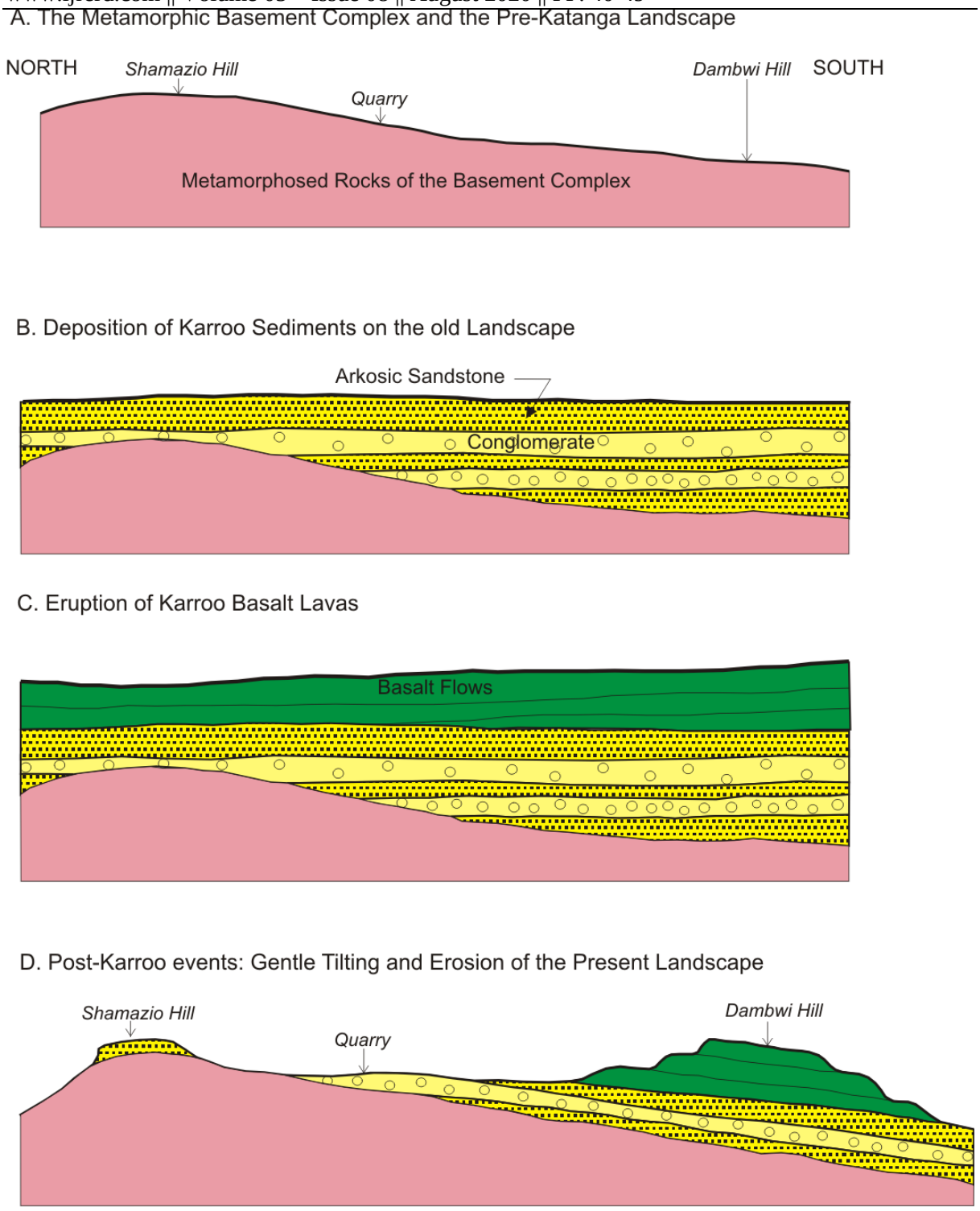


Figure 4: Cross-section showing Batoka Basalts at Chilileka, Kafue, Zambia

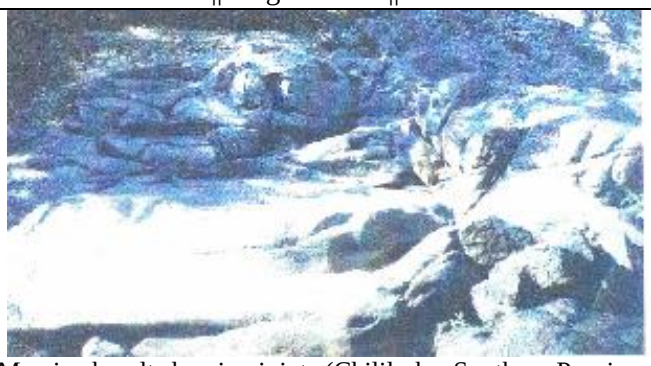
Upper Karoo Basalt with columnar joints(ZimbaTown, Southern Province)

Pillow lavas in Basalt(Chilileka, Southern Province)

Textures

Massive basalt

The rock is greenish black, fine to medium-granied, porphyritic. It occupies low or flat areas. Massive basalt are jointed and moderately resistant to weathering compared to amygdaloidal basalt. It is characterized by the well-developed columnar joints. The diameter of the joints is as much as 1 m.



Massive basalt showing joints (Chililerka, Southern Province)

Under the microscope the basalt shows the presence of plagioclase, pyroxene and olivine with a pronounced porphyritic texture.

Massive basalt

Vesicular basalt

Vesicles are regarded as small spherical or ellipsoidal cavities (Foriginating in volcanic rocks. They are formed by foams of gas stuck during the solidification of the rock. When lava erupts, stuck gases which are under high pressure relative to the atmospheric pressure escapes from the lava, leaving behind cavities. Hence alternating bands of vesicular and massive basalts seen in the study area infers that there were supplementary eruption episodes.

Vesicular basalt (on top of Dombwe hill)

Amygdaloidal basalt

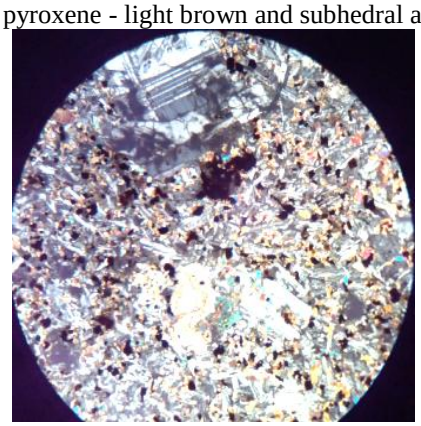
Cavities may later be occupied by secondary mineralisation i.e. amygdales, as mineralised fluids permit through the rock. These amygdales take diverse shapes contingent on the shape and size of the cavities. Different type of amygdale advances as minerals grow from the wall of the cavity, near the centre. The secondary mineralisation is mainly zeolite and calcite

Photograph of amygdaloidal basalt on the northen part of Dombwe hill

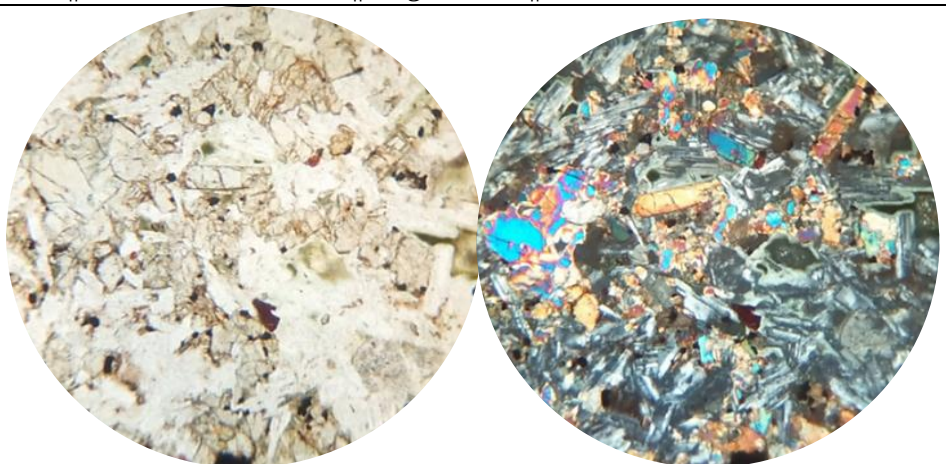
Petrography

Pyroxene phenocrysts. Tholeiite with normative quantities, high in Fe, Ti When flood basalts are forming above continents they fill rift valleys via giant fissures that split the continent. Magma migrates to the surface following these fissures, which are preserved as dikes Major flood basalts, large igneous provinces and trap

Massive basalt: he massive basalt is a dark coloured volcanic rock. It is fine grained porphyritic and moderately weathered. An intergranular type of texture is shown in the thin section. Composed of plagioclase feldspar - grey colour and subhedral-euhedral, pyroxene - light brown and subhedral and olivine – bluish purple, anhedral



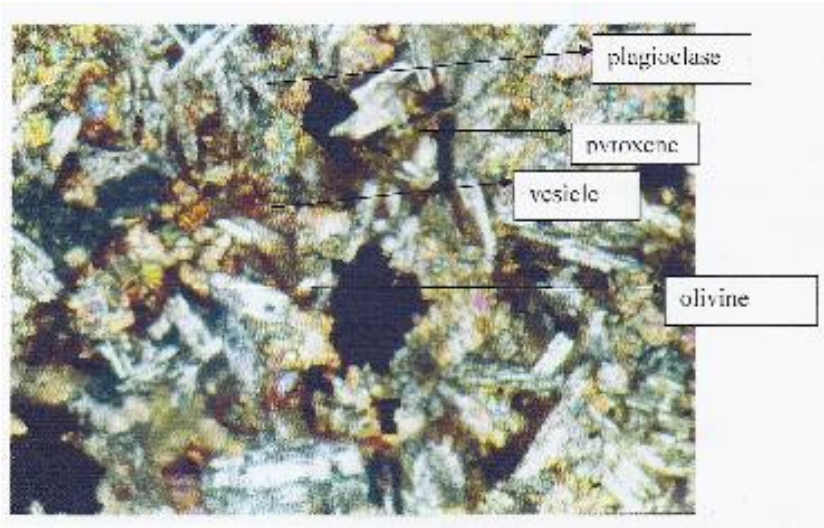
Photomicrograph of porphyritic massive basalt, under cross polarized light



Thin section of massive basalt showing pyroxene, olivine and plagioclase at x100 magnification under cross-polarised(a) and plain-polarized(b) light.(Px=Pyroxene, Ol=Olivine, Pl=Plagioclase)

Vesicular basalt:

The rock is fine grained with the presence vesicles, mineralogical it is composed of unoriented plagioclase lath, pyroxene (augite), hornblende, epidote, and anhedral grains of magnetite, and small amount of olivine.

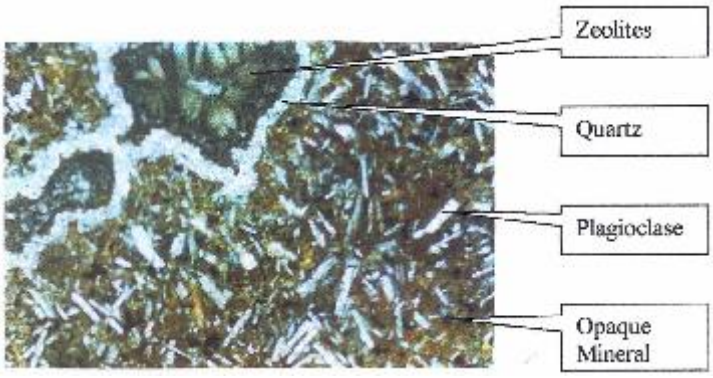


Photomicrograph of vesicular basalt, under cross polarized light

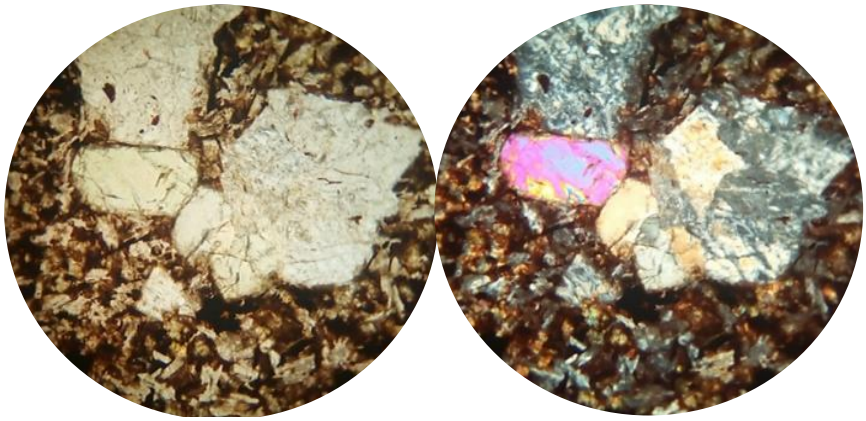
Amygdaloidal basalt:

The amygdaloidal basalt is purplish black in colour and very fine-grained consisting of vesicles filled with zeolite (Scolecite and mesolite), with innumerable amygdales of varying sizefilled largely with quartz and agate.

A thin section of an ophitic type of texture is shown in in that laths of fine-grained euhedral plagioclase crystals are enclosed in a large pyroxene crystal. The vesicles are filled with the mineral zeolite. Has a composition of pyroxene - brown, Subhedral-euhedral, olivine – purple, subhedral-euhedral.



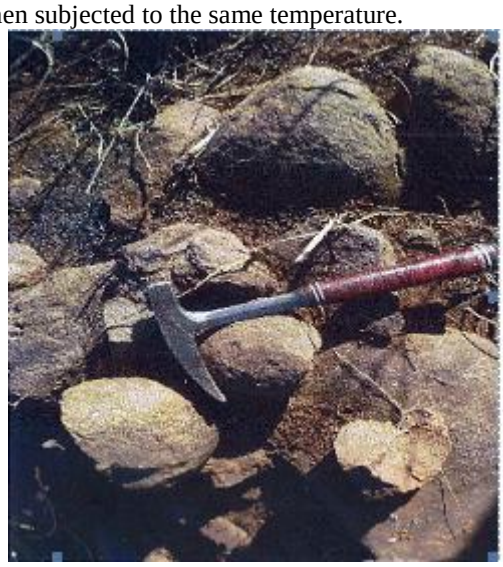
Photograph showing amygdaloidal texture. Plagioclase lath are randomly oriented



Thin section of amygdaloidal basalt showing agate at x100 magnification under cross-polarised(a) and plain-polarizedlight (b)

Exfoliation

Exfoliation (onion-skin weathering) as shown in , is a process of weathering whereby thin sheets of rock fragment off due to diverse expansion and contraction during heating and cooling over a diurnal temperature range. Rocks contain minerals which have different heat capacities. Hence, they expand and contract to different amounts when subjected to the same temperature.



Exfoliation weathering, basalt quary, Chilileka, Chikankata District, Southern Province

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