Deformational quartz textures and mineralogy of hydrothermal alteration associated with intrusion-related gold deposits: A case study from the Atud area, Central Eastern Desert, Egypt

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1. Introduction, literature and research review

Intrusion-related gold occurrences in Egypt are located in the Precambrian basement rocks of the Arabian-Nubian Shield (ANS) that are mainly confined to quartz-mineralized shear zones and very important as productive shear zones and quartz veins (Klemm et al., 2001). It is considered as the orogenic-mesothermal Au deposits hosted in gabbroic rocks.

The quartz veins are commonly formed within, or above the brittle-ductile shear zones around 2-3 kbar and 200-350°C in low-grade rocks (Bons, 2001), that is referred to these hydrothermal veins considered as syntectonic to post-tectonic. The quartz textures have been classified by Götze and Möckel (2012) into three major groups; primary, recrystallization, and replacement. Stipp et al., (2002), determined three main different dynamic recrystallization mechanisms; (1) Bulging recrystallization (BLG) which was dominant between ~280 and ~400 °C; (2) subgrain rotation recrystallization (SGR) which occurred at ~400-500 °C; and (3) the grain boundary migration recrystallization (GBM) that occurred at ~500 °C.

In this work, we study the deformational textures of quartz from mesothermal quartz veins and hydrothermal alteration minerals to define the nature and origin of the hydrothermal fluids as well as mechanism and environment of formation of quartz veins.

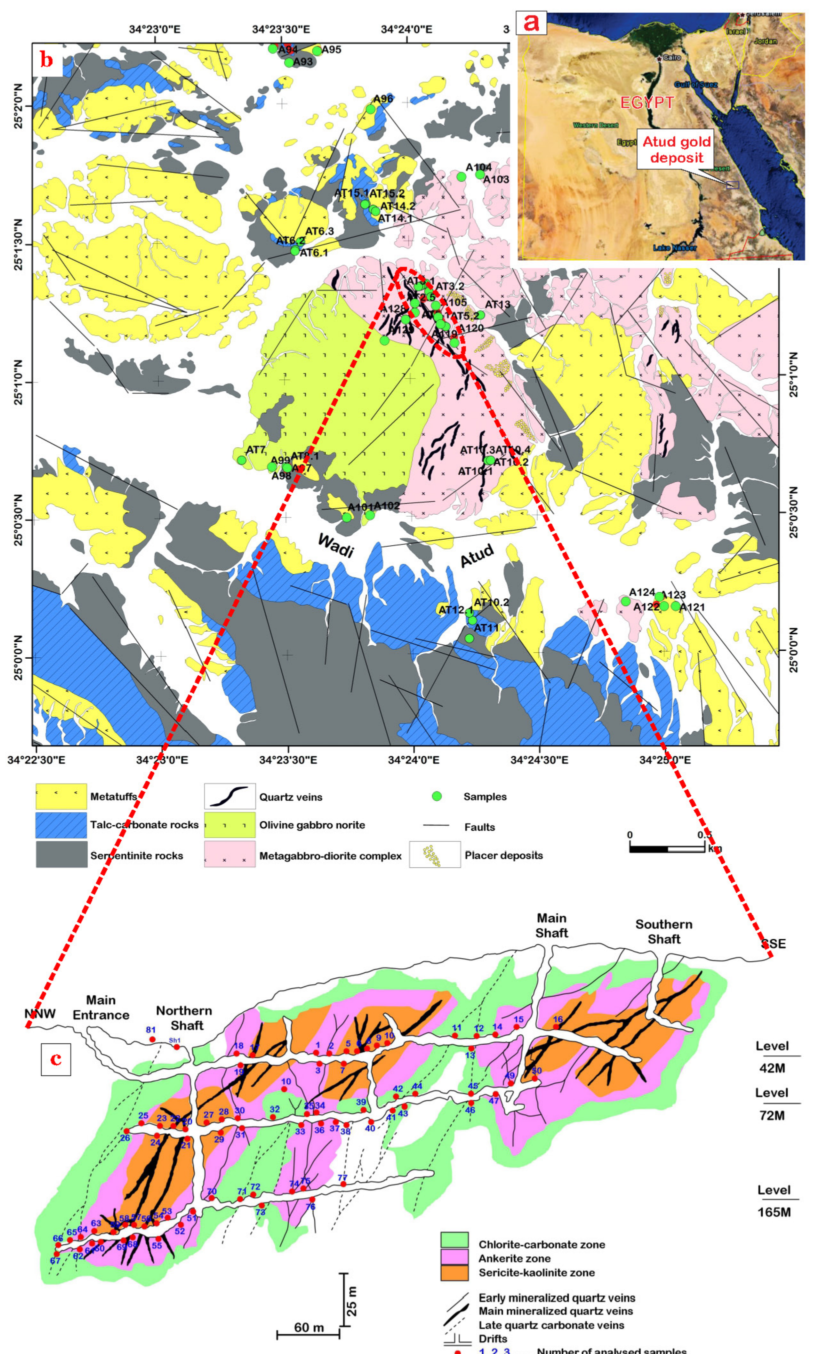

Figure 1: a) map of Egypt, b) Locations and geologic maps of Atud gold deposit (modified from Gabbra, 1986), c) Fig. 3. Longitudinal section of the Atud gold mine, Traced quartz vein stages and alteration zones are after Harraz (1999).

2. Methodology

Detailed geological mapping and field observations of the hydrothermal alteration and mineralization were carried out, and more than 160 samples were collected during field working campaigns. A detailed deformational quartz textures and hydrothermal alteration and mineralization studies were carried out using polarizing and ore microscopes, and X-ray diffractometer (XRD) in Geochemistry Research Laboratories of Istanbul Technical University (ITU/JAL), Istanbul, Turkey.

3. Geological and petrographical studies

Detailed field study of Atud gold mine area (Fig. 1b) revealed that the Atud gold mine area covers 18 km2, and composed mainly of metagabbro-diorite complex (Fig. 2a-2b) emplaced into serpentinites (Fig. 2a-2c) and talc-carbonate rocks (Fig. 2a-2c) and metasediments (Lapilli metatuffs (Fig. 2e) and Ash metatuffs (Fig. 2f)). This complex is later intruded by olivine gabbro norite (Fig. 2g). The Atud gold deposit area is traversed by many quartz veins (Fig. 2h) and dykes of different compositions (basic and intermediate).

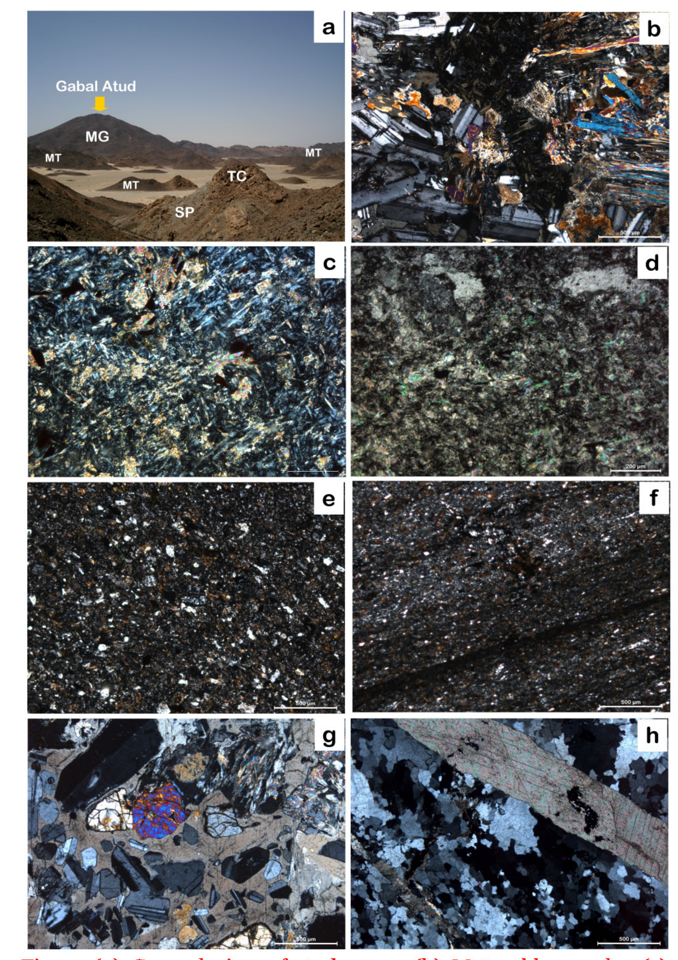

Fig. 2. (a) General view of study area, (b) Metagabbro rocks, (c) Serpentinite rocks, (d) Talc-carbonate rocks, (e) Intermediate lappilli metatuffs, (f) Ash metatuffs (schistose), (g) Olivine gabbro norite, (h) Quartz vein.

4. Atud Gold mineralization, quartz veins, and hydrothermal alteration:

4.1 Gold mineralization

It is located in the eastern and southeastern slope of Gabal Atud. It relates to a system of hydrothermal veins (quartz veins) along a NNW- to NW-trending shear zone, that occupy the pre-existing fractures (open-space filling) cutting through the metagabbro-diorite complex (Fig. 1b). In addition, it is associated with the metasomatic hydrothermal alteration zones, and is observed at the contact with the quartz veins and these zones (Harraz, 1999).

4.2 Quartz veins

Field and microscopic observations suggest that there are two generations of these quartz veins; (1) the old one is characterized by grayish to white, mineralized trending N 30°-40° W dipping around 45° toward W. (2) the younger vein generation is crystallized later, unmineralized, milky white, trending NE-SW dipping 15° toward NW (Fig. 3a-b).

(a) At the first level (Level 42m), the main quartz vein is comprised mainly of bluish or greyish quartz frequently associated with variable amounts of milky quartz (Fig. 3c). Greyish quartz veins that have ~ 50 cm thick directed N 20 W dipping 45 W, cut by small veinlets of milky quartz (Fig. 3d), and affected by shearing and deformation directed nearly N-S (Fig. 3e) causing brecciation. Pinching, swelling and bifurcation into small veins and veinlets are observed (Fig. 3f).

(b) At the second level (Level 72m), the main quartz veins extend discontinuously up to 270 m along with nearly 70cm thick, and are mainly milky quartz trending N 30-40 W dipping 55 W with variable amounts of bluish or greyish quartz (Fig. 3g).

(c) At the third level (Level 165m), high amount of milky quartz with smaller amounts of bluish or greyish quartz characterize the main quartz veins that directed N 40 W and cut by carbonate veinlets (Fig. 3h).

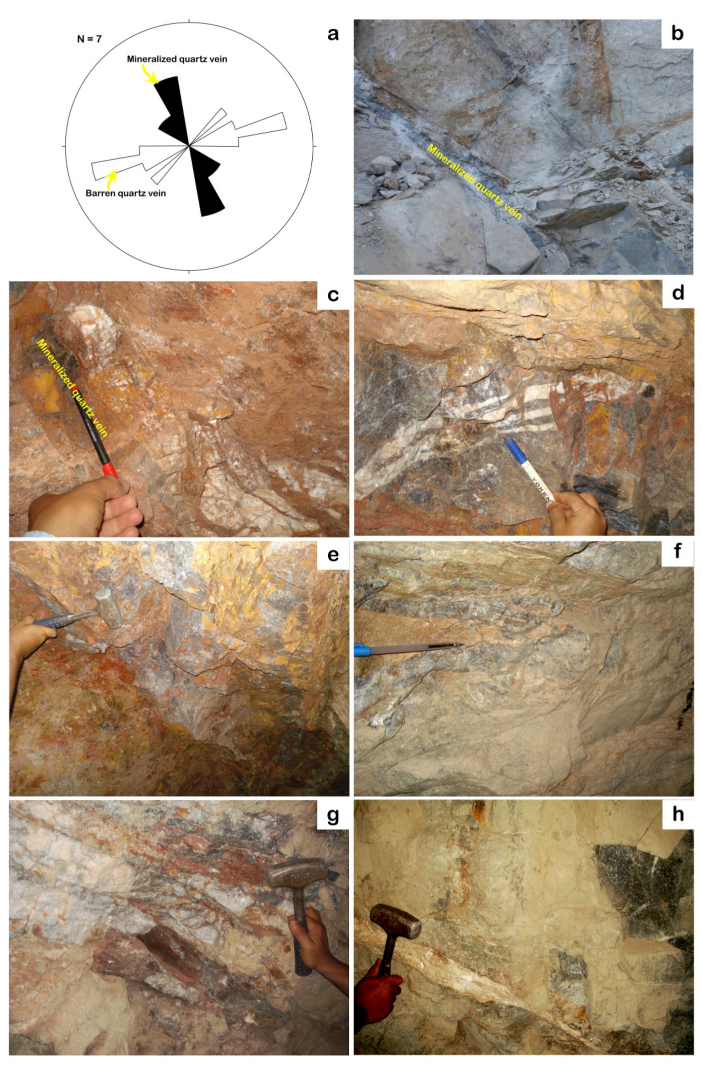

Fig. 3. (a) Rose diagram showing for two type of quartz veins, (b) mineralized quartz vein, (c) Grey quartz vein with milky one, (d) milky quartz veinlets cut through grey quartz, (e) shearing and deformation of grey quartz vein, (f) bifurcation of grey quartz veinlets, (g) milky quartz vein, (h) calcite veinlets cut quartz vein.

Different types of quartz veins in three stages of mineralization at Atud area based on the textural relationships of the various minerals observed; as following:

A) Early mineralized quartz veins characterized by presence of bluish- to dark-grey colored quartz veins ranging from few centimeters up to 1m thick (Fig. 4a). They are characterized by subhedral medium to coarse grained-quartz crystals with serrate grain boundaries (Fig. 4b).

B) Main mineralized quartz veins are closely associated with sericite-kaolinite±albite alteration zones (Fig. 4c-d), locally have carbonates and graphite (Fig. 4e). They are laminated veins (Fig. 4e), exhibiting numerous features representative of ductile deformation (Fig. 4f). Their quartz characterized by euhedral to subhedral, coarse grained-crystals, traversed by a network of fine cracks commonly filled with milky quartz (Fig. 4g). They also have undulose extinction and granulated grain boundaries. This refers to **bulging recrystallization (BLG) deformation** with bulged and recrystallized subgrains along the boundaries of the original quartz grain boundaries (Fig. 4h) that occurred at temperatures of around 280 to 400°C of Stipp et al., (2002). Gold occurs as microscopic inclusions in arsenopyrite and pyrite.

C) Late quartz-carbonate veins ranging from few centimeters to 0.6m thick post-dated all other quartz types, comprising milky quartz and calcite with pyrite (Fig. 4i-j).

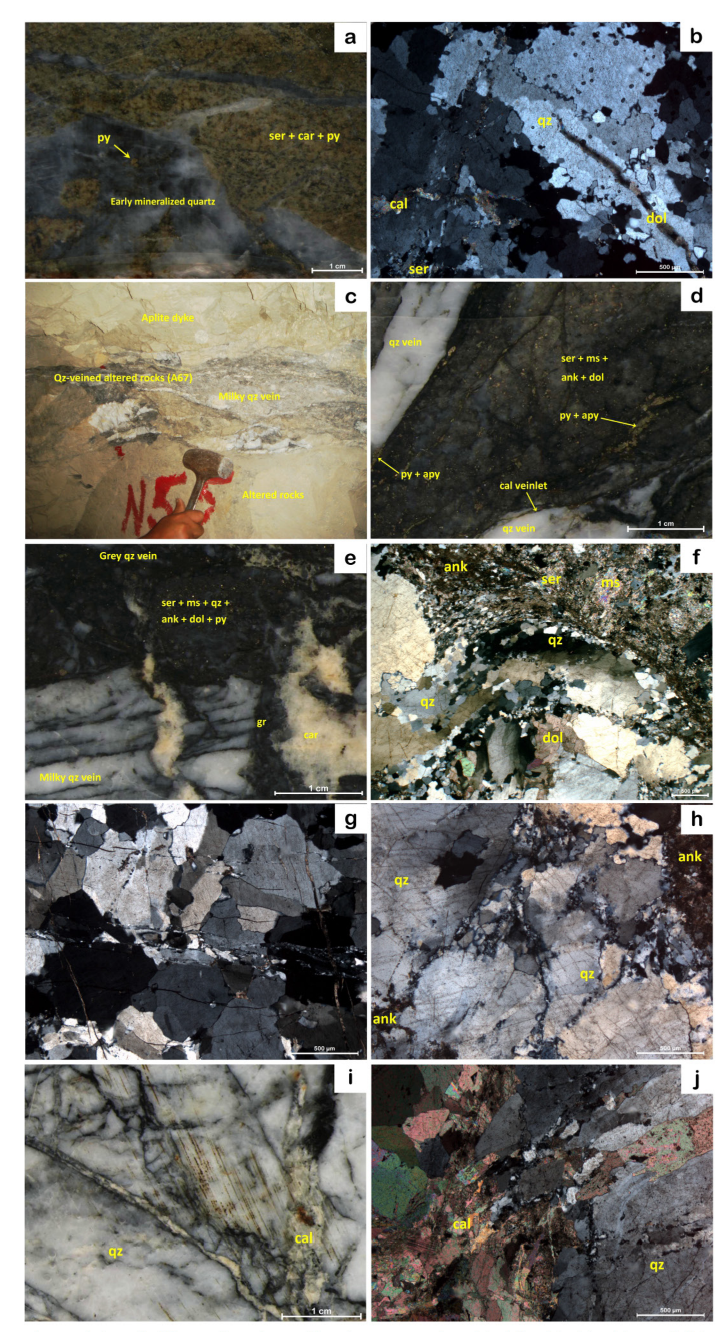

Fig. 3. (a) and (b), Early mineralized quartz vein. (c), (d), (e), (f), (g), and (h) for mineralized quartz veins, and (i) and (j) for quartz carbonate veins.

4.3 Hydrothermal alteration

Three main hydrothermal alteration zones of mineral assemblages with gradual boundaries occurred around quartz veins and associated with the main shear/fault zone trending NNW-SSE. These zones are distinguished based on geological and petrographical data as well as XRD analyses (Fig. 5 & 6);

(1) Zone 1: sericite / kaolinite + muscovite + quartz + pyrite ± graphite ± ankerite ± dolomite ± albite), (Fig. 5a-b & 6a-b),
(2) Zone 2: quartz + albite + sericite / kaolinite ± pyrite ± dolomite ± clinochlore ± muscovite), (Fig. 5c-d & 6c),
(3) Zone 3: carbonate (ankerite + calcite) +chlorite (chamosite + chlinochlore) + albite ± pyrite ± arsenopyrite ± muscovite ± quartz), (Fig. 5e-f-g-h & 6d).

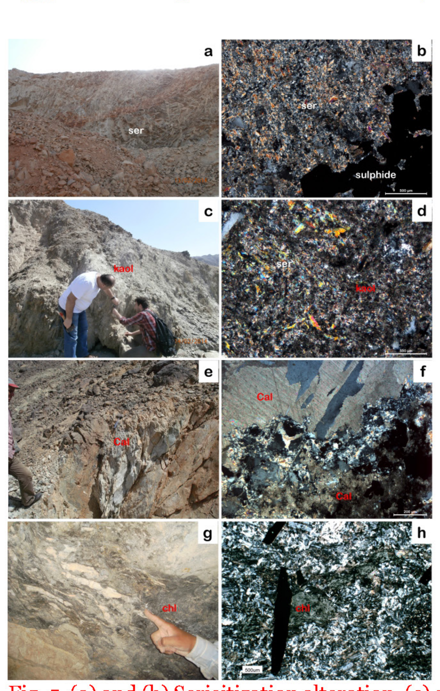

Fig. 5. (a) and (b) Sericitization alteration, (c) and (d) kaolinitization (e) and (f) carbonatization, (g) and (h) Chlorotization.

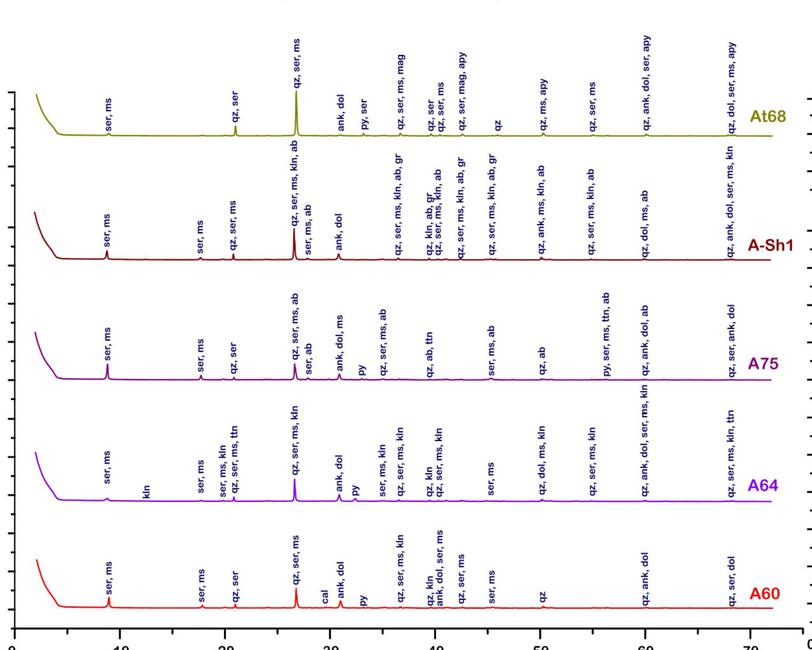

Fig. 6a. XRD patterns of samples of zone-1 in Atud area.

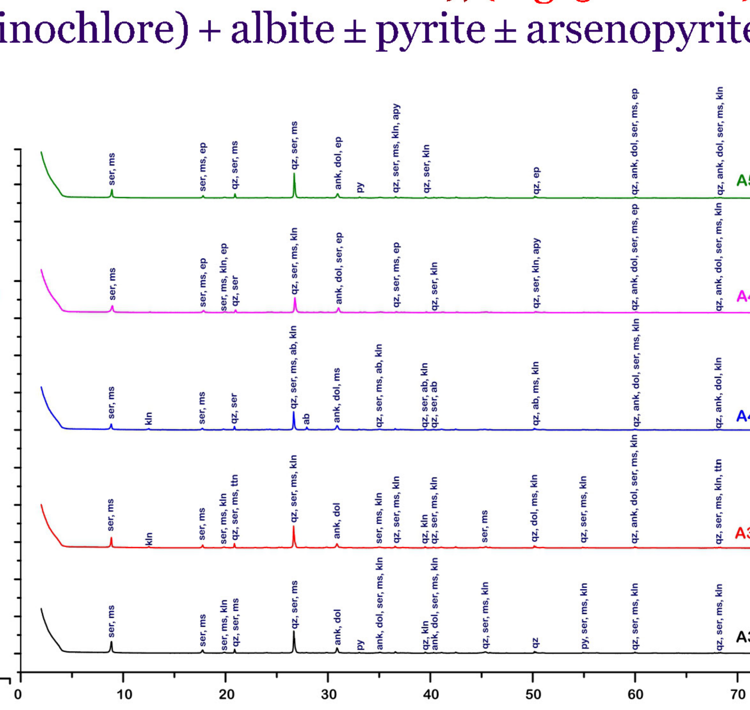

Fig. 6b. XRD patterns of samples of zone-1 in Atud area.

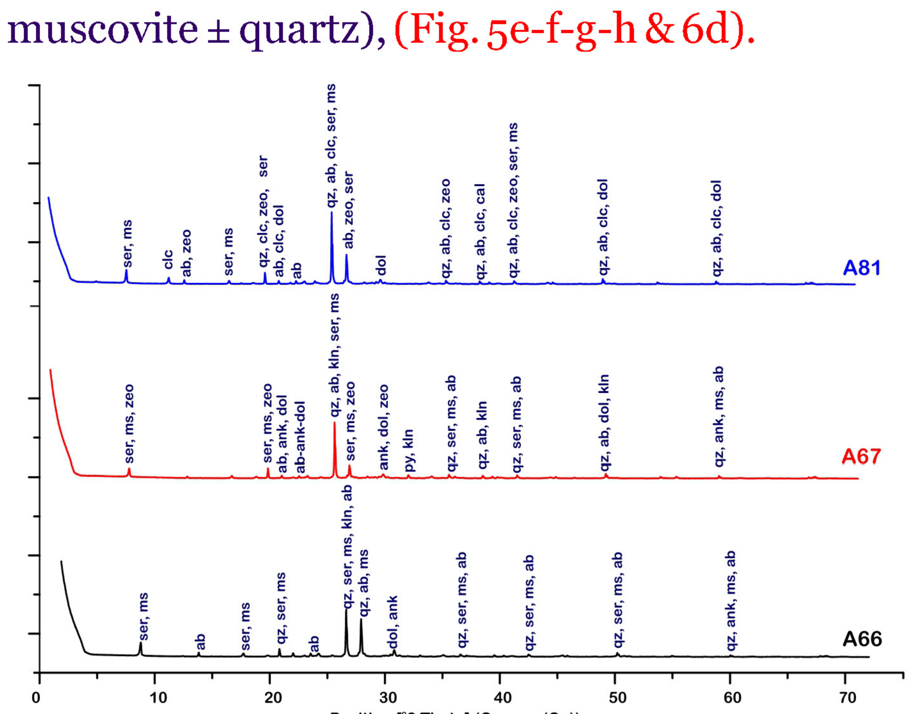

Fig. 6c. XRD patterns of samples of zone-2 in Atud area.

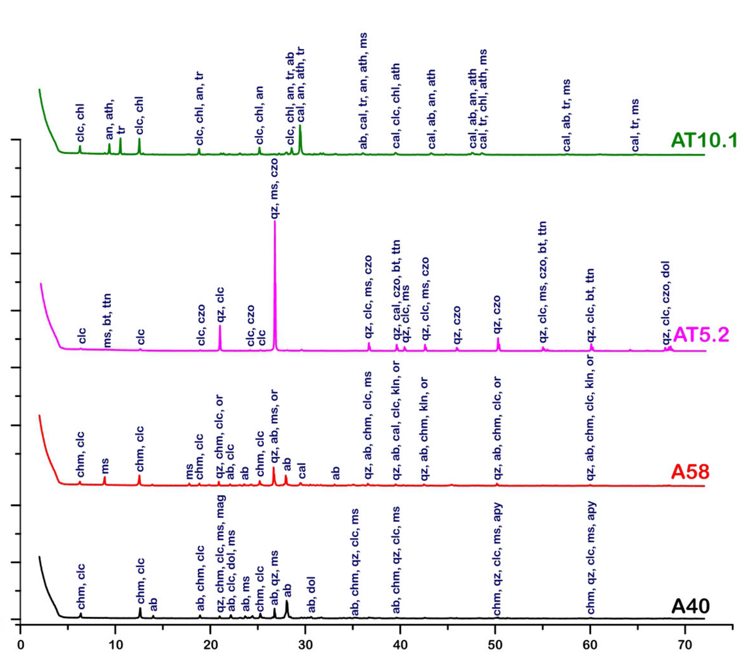

Fig. 6d. XRD patterns of samples of zone-3 in Atud area.

5. Conclusions

- Gold mineralization in the Atud gold deposit is mainly associated with quartz and hydrothermal veins that occupy pre-existing fractures (open-space filling).
- There are two generations of auriferous quartz in the Atud gold mine; the oldest one is NNW-SSE, while the younger is NE-SW
- The mineralized veins largely exhibit bulging recrystallization (BLG) deformation with bulged and recrystallized grains at the quartz grain boundaries that occurred at temperatures of around 280 to 400°C of Stipp et al. (2002). According to Passchier and Trouw (1996), the undulose extinction and deformation lamellae in quartz assumed that these veins formed under conditions of 300-400 C.
- X-ray Diffraction (XRD) data revealed that the hydrothermal alteration minerals associated with gold mineralization are mostly quartz, pyrite, sericite, Kaolinite, and dolomite with selective ankerite, chlorite, and albite.