CHAPTER 3

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Chapter-3

Geological Background & lithology

3.1 Geological Setting of the study area:

The Chitrial outlier, made up of rocks of the Srisailam Formation, occurs at the northwestern tip of the Srisailam sub basin and is surrounded by basement granitoid rocks of the EDC. The outlier is a horse shoe shaped flat topped ridge occupying 60 sq km area with rocks of the Srisailam quartzite exposed at the top and granitoid rocks occurring all around as well as between its two arms (Fig. 3.1). The thickness of the cover sediment of the Srisailam Formation varies from 6 to 80 m in the outlier. The unconformity plane between the basement granitoid rocks and the overlying Srisailam quartzite is very well exposed in hilly road sections on to the Chitrial village (Fig. 3.2) which falls into the toposheet nos. 56L/13, 56L/14 and is located between latitude-longitudes N 16^0 29' 42.3" and E 78^0 56' 28.3" to N 16^0 34' 45" and E 79^0 04' 55.2". In Reggalagudda, (Fig. 3.1), at the easternmost part of southern arm, a thick sequence of cover sediments underlain by granite is exposed in a vertical section of about 60 m. Basement granite is exposed in the low land between the two arms near Dasarapalli and Chitrial villages. Primary sedimentary structures including stratification, ripple marks, cross stratifications, laminations, and syn-sedimentary deformation structures are present in these sediments (Latha *et al*., 2009) which collectively point to a normal stratigraphic succession.

According to Verma *et al*. (2008), the thickness of cover rocks varies from west to east. From subsurface exploration it has been documented that the thickness varies from 1m to 35m in the western sector to 10m to 80m in the eastern sector. Stratigraphic succession of the Chitrial area is presented in Table 3.1 (Verma *et al*., 2008). At Chitrial, the ca. 1.7 Ga Mesoproterozoic Srisailam Formation (Collins *et al*., 2015) nonconformably overlies the S-type granitoid basement with reported U-Pb zircon age of ca. 2.51-2.52 Ga (Mukherjee *et al*., 2018). The basement granite is intruded by pegmatites, epidote, chlorite and quartz veins. Verma *et al*. (2008), on the basis of geochemical data, classified these granitoids as A-type. According to Rajaraman *et al*. (2013), the granite shows highly evolved nature with enrichment of potassium indicating a lower crustal source. However, presence of discrete carbonaceous phases reported within granites indicate low temperature and high pressure melting of sedimentary protolith (Latha *et al*., 2009) to produce the granitic melt.

The contact between the basement granitoid and overlying sediments of the Srisailam Formation is occasionally marked by the presence of 3 – 5 m thick weathered and altered granite indicating a zone of chemical weathering and a period of nondeposition. An important characteristic of the Chitrial area is the occurrence of uranium mineralization hosted in porphyritic biotite-granite underlying unmetamorphosed sediments of the Mesoproterozoic Srisailam Formation.

3.2 Litho-units of the study area

The main lithologies of the study area include the basement granitoids and the overlying sandstone-shale units of the Srisailam Formation. Mafic dykes of varying orientations intrude the granitoids but get truncated by the lower surface of the Srisailam Formation outcrop indicating their earlier formation. Uranium enrichment is reported from the granitoids as well as the overlying rocks of the Srisailam Formation.

3.2.1 Basement granitoids

Megascopically, Chitrial granitoids are medium to coarse-grained, leuco – to mesocratic, holocrystalline, pink and grey in colour. The basement granitoids are represented by three major variants viz., massive granite, porphyritic granite and granite gneiss (Mukherjee *et al*., 2018). The contacts between the pink and grey granites are gradational (Fig. 3.3a). The basement granitoids are undeformed at most places and represents the massive variety (Fig. 3.3b,c) which at places is replaced by a porphyritic variety with elongated feldspar phenocrysts in cryptocrystalline quartzo – feldspathic groundmass (Fig. 3.3d). In such areas, the subhedral and anhedral quartz and feldspar grains in the undeformed granite shows interlocking texture while biotites form clusters and do not show any preferred orientation (Fig. 3.3e). In the pink granite the pink colour is induced from the presence of microcline. This variety is also porphyritic in nature and essentially composed of microcline, quartz, with subordinate amount of plagioclase and biotite. The effect of later shearing is very little in this variety of granite. The massive grey granite is interspersed with small, isolated gneissic pockets (Fig. 3.3f) where the dominantly NW-SE trending gneissic foliation is defined by alternate quartzo – feldspathic and biotite-rich layers. At places, the granites are affected by conjugate mesoscopic shear zone development and the massive to gneissic fabric changes to a mylonitic fabric (Fig. 3.3g).

In the study area, a suite of mafic enclave is found within the granites which are dominantly consisting of oriented biotite grains with minor muscovite and chlorite. These enclaves are devoid of chilled margin and possibly represent relics of older supracrustals present prior to the emplacement of the granite in the area. These mafic enclaves are stretched, elliptical and define a shape preferred orientation on plan which suggests syn-magmatic deformation (Fig. 3.3h,i,j). Weak effects of late brittle deformation episodes are evident from the basement granites and gneisses around Chitrial with development of shear and mixed-mode fractures (Figs. 3.4a,b,c) of variable orientations. At places, the original texture of granitoids is partly modified due to fracturing accompanied by mineral alteration and cataclasis (Fig. 3.4d). Post-Srisailam regional faults trending N-S as well as WNW-ESE displace the outcrops at places and thus indicate large-scale late basement reactivation in the area. Mesoscopic faults in basement granitoids shows two distinct directions along NW – SE and NE – SW with a less developed directions of N – S and E – W (Verma *et al*., 2009).

3.2.2 Mafic Dyke

Mafic dykes (*ca*. 1.9 - 1.8 Ga emplacement age) of three different orientations (trending N-S, WNW-ESE and ENE-WSW) traverse the granites around the Chitrial outlier (French *et al*., 2008) which are older than the Cuddapah sediments. These dykes are usually several meters thick, run few hundred meters along strike and sub-vertical to vertical (Figs. 3.5 a, b) in orientation. One such very thick dolerite dyke, trending N30°W, is exposed along the road in the northern arm of Chitrial outlier. Though the dykes are in general fine-grained, melanocratic and greyish-black in colour, textural variation is commonly observed in these dykes with cores being medium to fine grained while walls displaying a chilled margin. The Chitrial outlier is surrounded by such NW – SE, NE – SW and NS trending dykes (Murthy, 1995; Verma *et al*., 2008).

3.2.3 Veins

Epidote, chlorite, pegmatite and quartz veins traverse the granitic rocks in the region (Fig. 3.5c). These fracture filling veins are the evidence of hydrothermal activity within the terrain. Effects of extensive hydrothermal alteration are recorded in wall rock granites occurring adjacent to these veins resulting in widespread chloritisation and sericitisation of the basement granitoids. The veins cut through the granites as well as the dykes and appear to mark the youngest intrusive event within the basement rocks.

3.2.4 Srisailam Formation

The rocks of the Srisailam Formation are mostly represented by thick sandstone units interspersed with shale and siltstone layers (Fig. 3.6a). The sub-horizontal nature of the sandstone gives rise to the typical 'MESSA' type geomorphological features in the area. The Srisailam Formation in the study area is mainly represented by an arenaceous unit with subhorizontal bedding with thickness varying from 1 to 50 m and usually commence with a gritty or pebbly sandstone horizon above the unconformity. The sandstones are abound with primary sedimentary structures such as plane laminations, cross beddings and wave ripples of various geometries indicating deposition in shallow water wave-current dominated settings. Thin shale and siltstone horizons intersperse with thicker sandstone layers in the sequence. Sandstones are mostly medium to coarse grained, sub angular to sub rounded, well sorted with matrix containing clay, sericite, chlorite and cement is of siliceous to ferruginous (Lakshminarayana *et al*., 2001) composition. Various studies on Srisailam Formation have indicated cyclic variation in sedimentation pattern and suggested predominance of shallow marine to tidal flat or near shore depositional environments (Nagraja Rao *et al*., 1987; Vijayam and Reddy, 1976; Lakshminarayana *et al*., 1999, 2001). Basu *et al*. (2017) suggested continental half-graben basins as the depositional sites of the Srisailam Formation by analysing the sedimentary facies from the sandstones of the Chitrial area. These authors also suggested that deep lacustrine and prodelta facies depositional environments are represented by the shale layers which occur in the lower part of the sandstone. The shales are somewhere black in colour and have been derived from felsic igneous source rocks though from some trace elemental ratio indicate a heterogeneity of the provenance (Basu *et al*., 2017). Apatite is present as accessory mineral within the shale (Fig. 3.6b).

Outcrop studies indicate that mafic dykes are older than the sediments and these do not intrude the cover rocks. Thin conglomerate and palaeosol horizons can be locally observed to have developed along the prominent unconformity surface present between the granite and the Srisailam Formation. Based on sub – surface exploration in Chitrial area, thickness of cover rocks varies from < 1m to 35m in western sector and 10m to 80m in eastern sector (Verma *et al*., 2009).

3.3 Uranium enrichment

Intensive exploration efforts during the last two decades by the AMD have established several small tonnage medium grade unconformity related uranium deposits around Srisailam sub – basin where fertile basement granites are considered to be potential source for uranium mineralization (Sinha *et al*., 1995, 1996; Jeyagopal *et al*., 1996; Verma *et al*., 2008, 2011; Umamaheswar *et al*., 2009). Though marginal parts of Srisailam sub-basin has shown high uranium potential, the grade of mineralization and size of deposits are moderate (Banerjee *et al*., 2012). It is known elsewhere in the world that higher grade and large tonnage unconformity associated uranium deposits are mainly confined below the thick pile of sedimentary cover (Dahlkamp, 1993), which has played a definite and significant role in enrichment of uranium (Gandhi, 2007; Jafferson *et al*., 2007a,b).

In the present study area, uranium-mineralization is essentially confined to the basement granite near its contact with the overlying Srisailam Formation. It occurs in close proximity to the unconformity surface between the granitic basement and the overlying undeformed sandstone (Verma *et al*., 2009; Sinha *et al*., 1995) of the Srisailam Formation. Unconformity type uranium deposits are reported by AMD from Proterozoic age sediment outliers like Chitrial, Lambapur-Peddagattu, Koppunuru and Amrabad outliers where granite gneisses and K-feldspar rich biotite granites are unconformably overlain by Meso – Neoproterozoic Srisailam sediments and represents the evidence of both pre- and post-depositional reactivations by fracturing and faulting. Different phases of magmatism and tectonism probably lead to mobilization and remobilization of various metals, thus making the area more favorable for mineralization. Significant surface radioactive anomalies, with values up to 0.177% U_3O_8 (n=9) along the basement granitoid – Srisailam Formation contact led to the establishment of a sizeable uranium deposit by the AMD in recent years from the Chitrial area (Umamaheswar *et al*., 2009). From the surface radiometric survey data, Verma *et al*. (2009) indicated the presence of uraniferous occurrences, associated with basement granites, basic dykes and pebbly Srisailam quartzite, close to the non-conformity between the basement rocks and the Srisailam Formation. Samples of the basement granite (n = 65) assayed up to 0.177% U_3O_8, 0.317% U_3O_8 and <0.005% ThO_2, whereas those of basic dyke (n = 4) assayed up to 0.044% U_3O_8, 0.065% U_3O_8 and 0.056% ThO_2. AMD has established 20000 tones of low to medium grade U-deposits in Srisailam Sub-basin (Ramesh Babu *et* *al*., 2012) in which more than 90% of ore body is confined to granite, occurring at depths of 3 to 82 m at Chitrial.

According to Verma *et al*. (2009), the Chitrial outlier can be sub-divided into five blocks according to decreasing U-enrichment, from the Main Block to the Block 4 (Fig. 3.6). Subsurface correlation sections reveal that the U-mineralization of the Chitrial area persists in grade and thickness along the nonconformable contact between the basement biotite granitoid and the overlying Srisailam Formation and continues over a strike length of 2 km. The average thorium and uranium contents in the Chitrial granite are 66 ppm and 53 ppm respectively whereas the U/Th ratio varies from 0.07 to 20.86 with an average of 1.68 (Rajaraman *et al*., 2013). Pedogeochemical sampling has also been carried out from Chitrial area by AMD on a grid of 1Km x 1Km and various trace elements were analysed for identifying the dispersion pattern (Bhoopathi *et al*., 2013). According to Sinha *et al*. (1995) and Ramesh Babu *et al*. (2012), the Srisailam Sub-basin, consist of richer grade uranium deposit which occur as linear pods trending WNW-ESE, N-S in Chitrial. According to Rajaraman *et al*. (2013), uranium enrichment and potassic alteration took place simultaneously in the Chitrial granite and uranium scavenged during the potassic alteration, have been remobilized and precipitated near the unconformity. Figure 3.7 shows a structural cross section showing the disposition of the uranium enrichment in the Chitrial outlier (Umamaheswar *et al*., 2009). These deposits have been the subject of intense research during the last couple of years in order to decipher their genesis. However, there exists a lacuna in understanding the role of deformation of basement granites vis-à-vis the covering sediments in facilitating the mineralization. Detailed geological data on mode of occurrence of uraniferous horizons, detailed geochemistry of uraniferous zones and their host granitoid rocks and geochronological dataset from different litho-sequences in the Chitrial area are grossly lacking. For this reason, establishments of the chronological events in this part of the EDC as well as syn- to post-kinematic remobilization of uranium with respect to basement and cover sediments, if any, remains poorly understood. The nature and evolution of major fault zones in the basement are keys to understanding the origin and structural controls of uranium deposits as they act as channel-ways and depositional sites for the metal bearing fluids. Thus, the present study aims to conduct field geological investigations supplemented by grain scale deformation studies with the aim of obtaining the complete and accurate account of the structural makeup of the rock mass for elucidating its kinematic history and role in uranium mineralization.

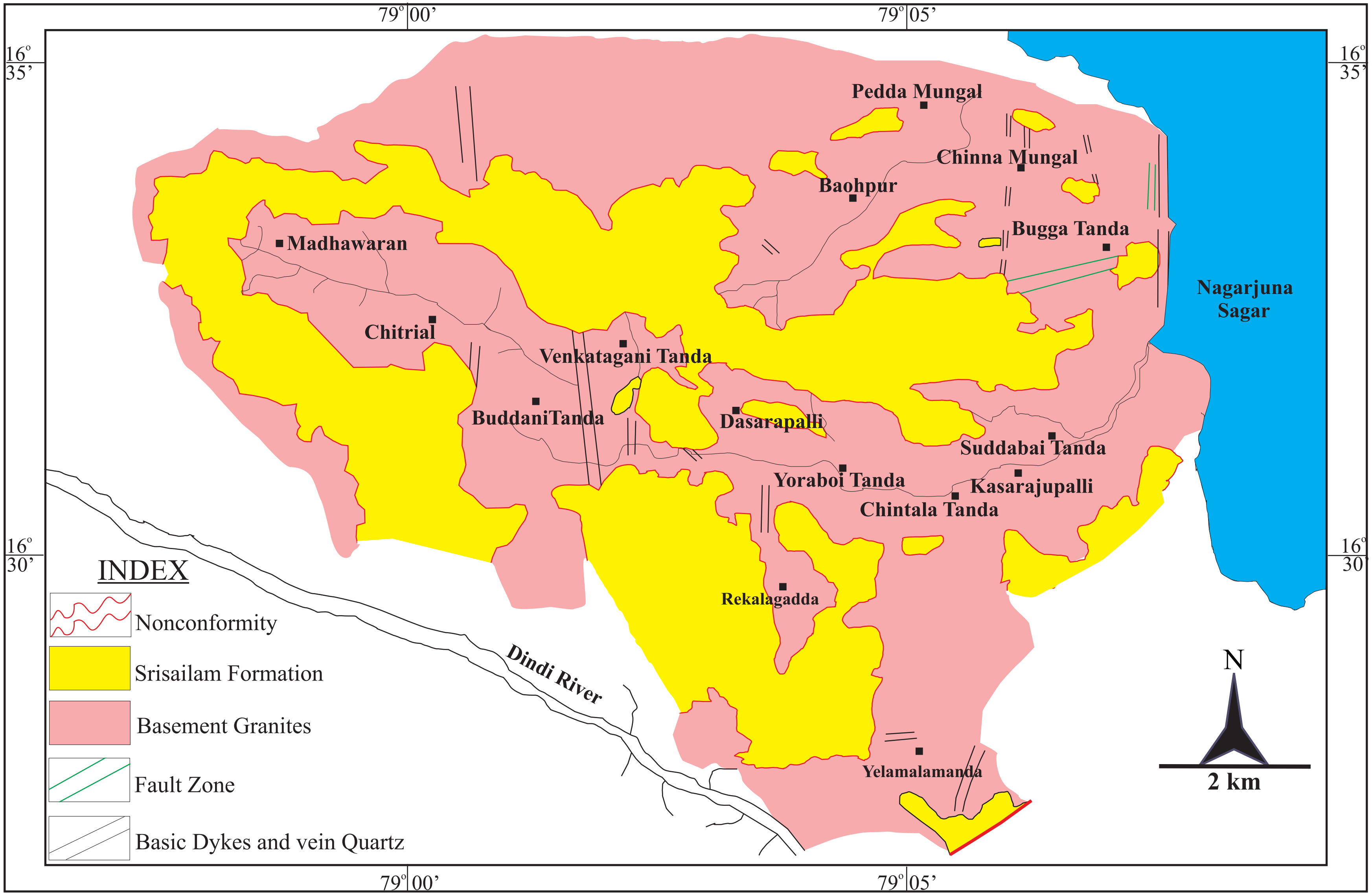

Figure 3.1: Geological map of the Chitrial Outlier, (modified after *Verma et al., 2009*)

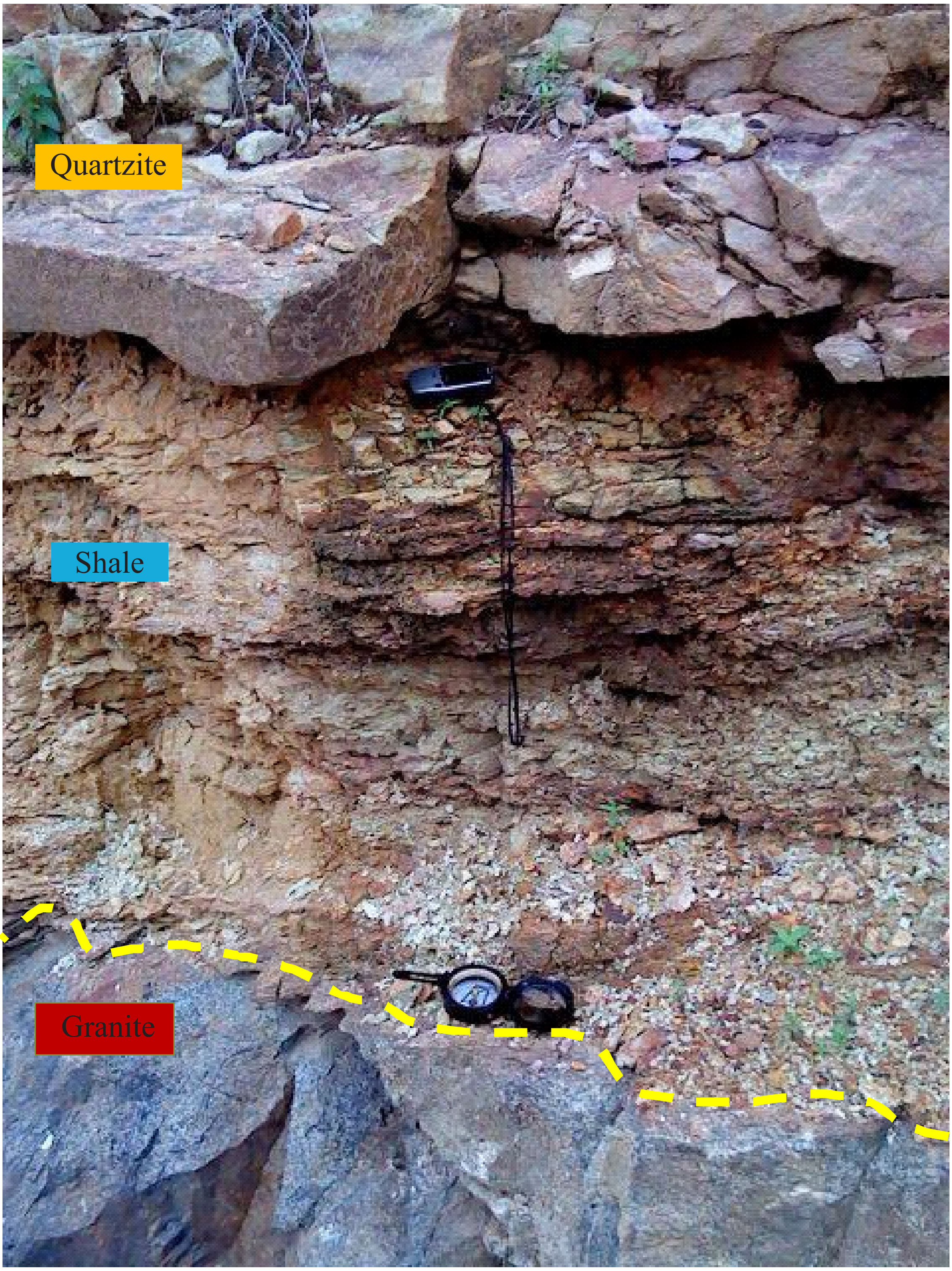

Figure 3.2: Unconformity contact (marked by yellow dash-line) between basement granite and cover sediments.

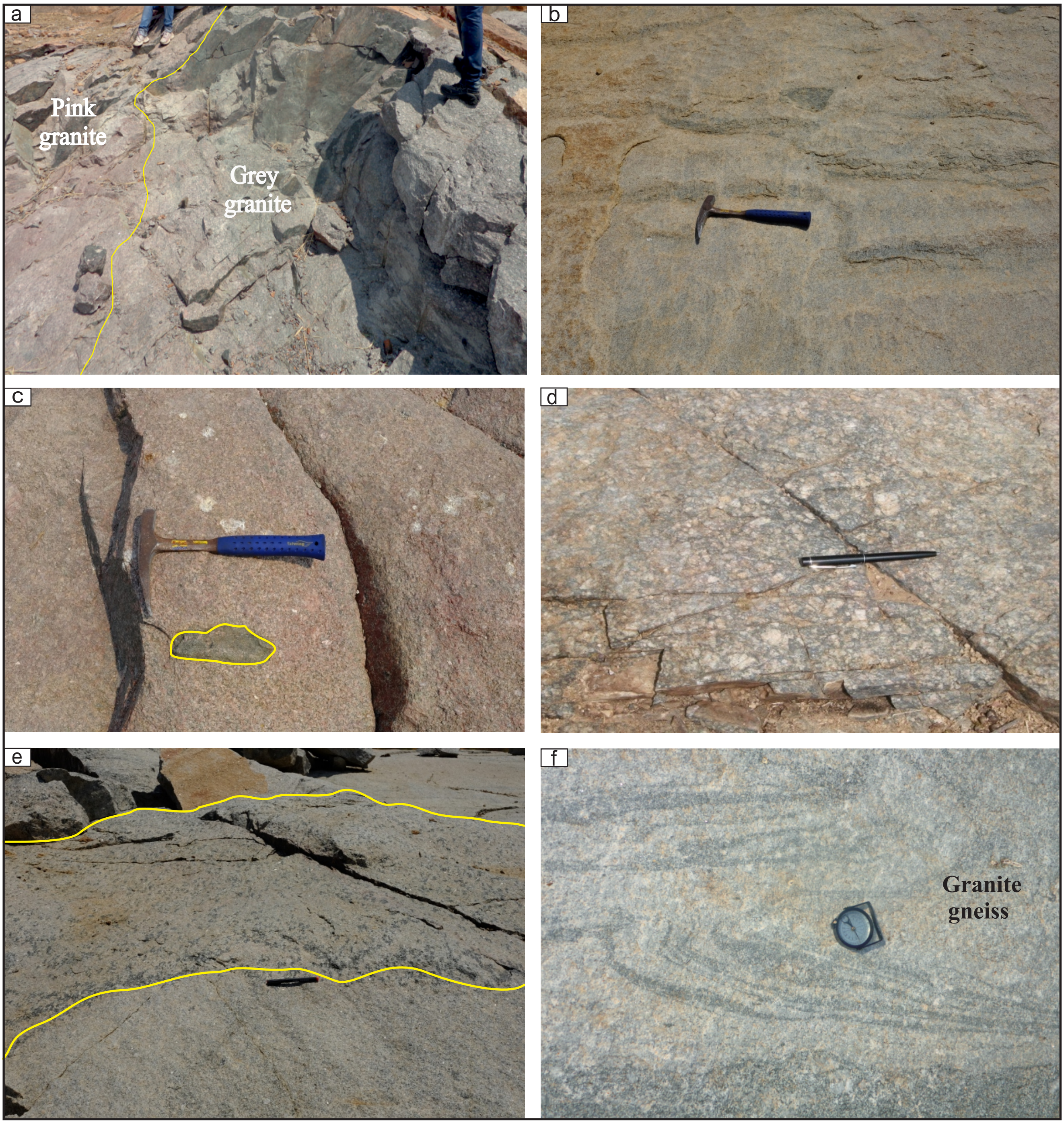

Figure. 3.3: Field photographs showing (a) Gradual change of grey granite to pink granite, (b) Grey massive granite, (c) Pink massive granite, yellow line show the mafic enclave present within granite (d) Porphyritic granite, (e) biotite presents as clustures within massive granite, (f) gneissic layering presents within grey granite.

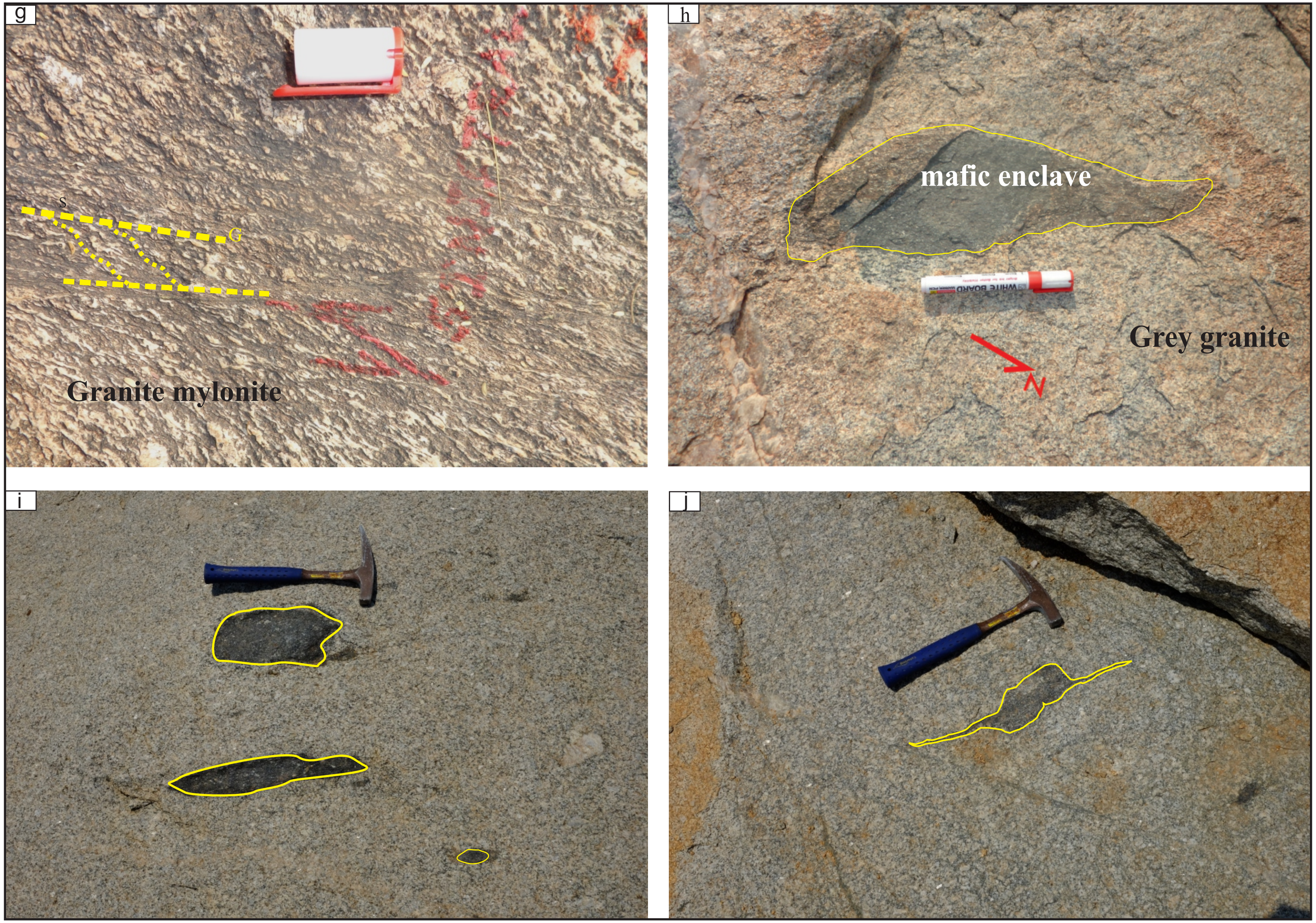

Figure. 3.3: Field photographs showing (g) Gneissic fabric changes to a mylonitic fabric with sinistral slip sense, yellow line denotes the gneissic foliation, (h) and (i) Elliptical and stretched mafic enclaves within granite, and (j) Enclave shows the deformational effect.

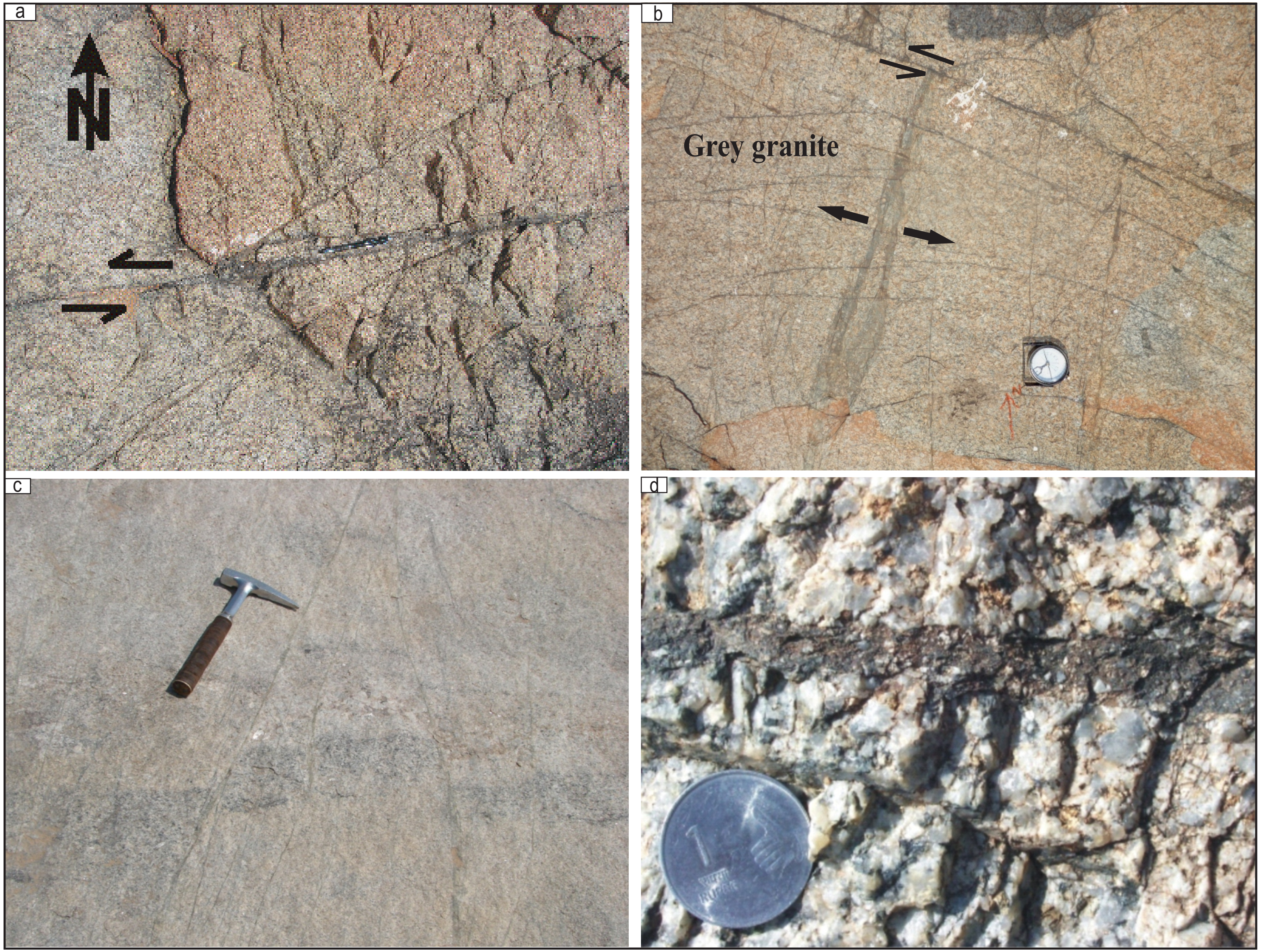

Figure. 3.4: Field photographs (a) and (b) A late brittle deformation affects the basement rocks and both shear and mixed-mode fractures of variable orientations develop. (c) Conjugate fracture displaces the layering within granite. (d) Original texture of granite is partly modified due to mineral alteration and local granulation develop within granite.

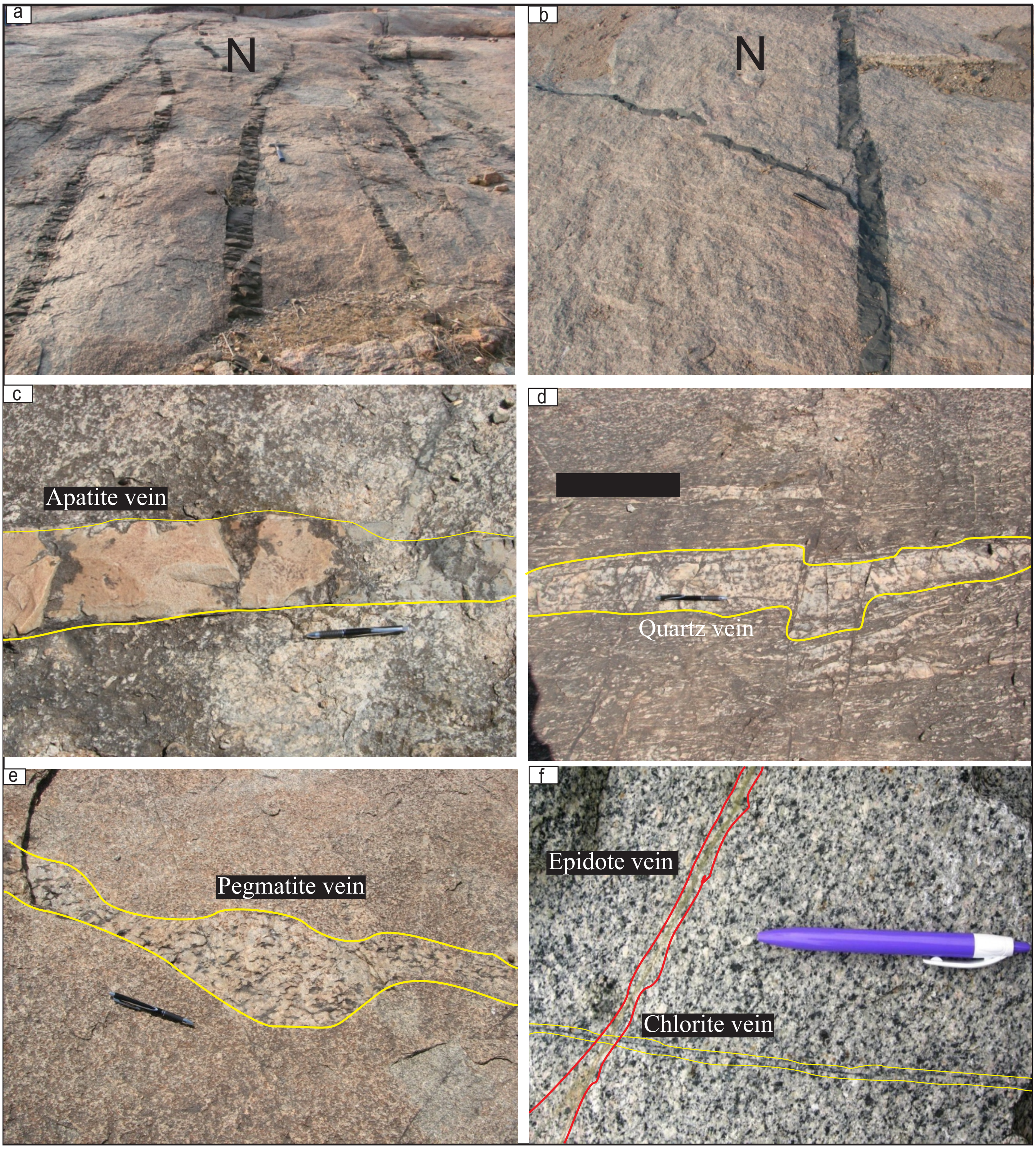

Figure. 3.5: Field photographs (a) and (b) N - S extension and several meter thick basic dykes emplaced and traverse the Chitrial granite, (c) Apatite veins present (marked by yellow line), (d) Quartz vein (marked by yellow line) presents within basement granitoid, (e) Pegmatite veinspresent within basement granitoid, (f) Chlorite veins marked by yellow colour and epidote vein marked by red colour.

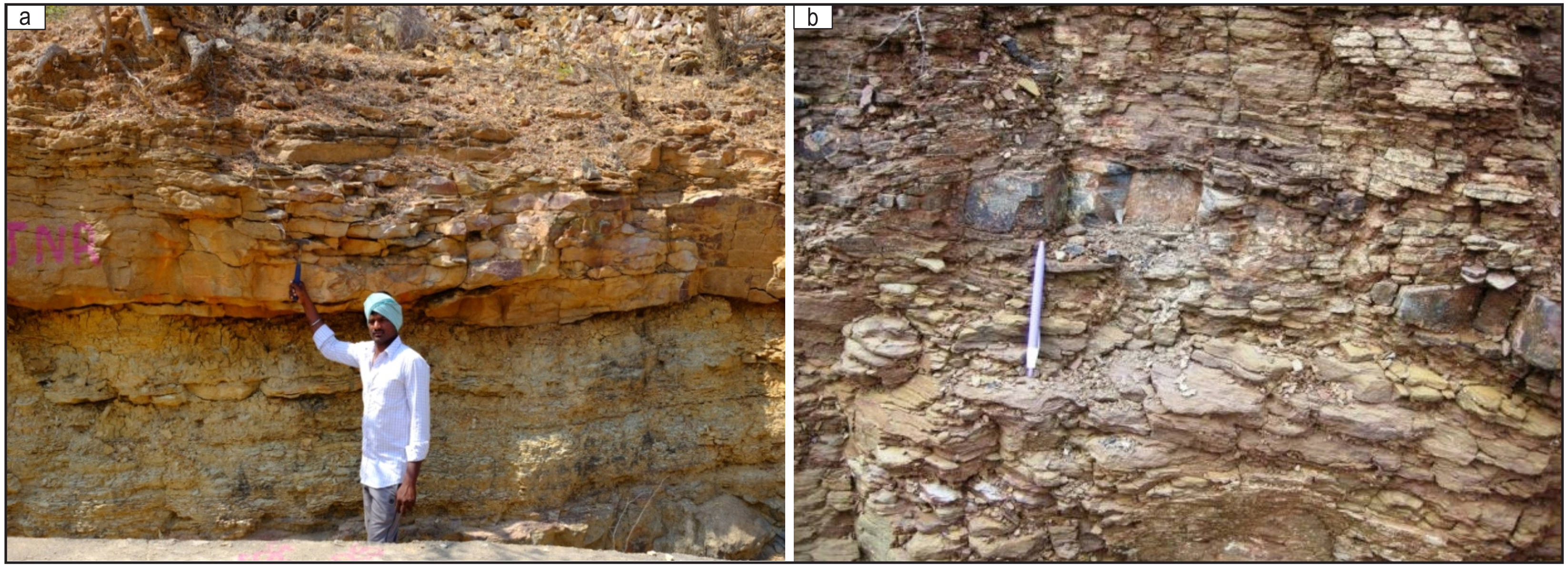

Figure. 3.6: Field photograph (a) Cover sediment consists of sub horizontal sandstone layer intercalated with shale and siltstone, (b) Lenticular aggregates of apatite (black colored, above pen) presents within shale.

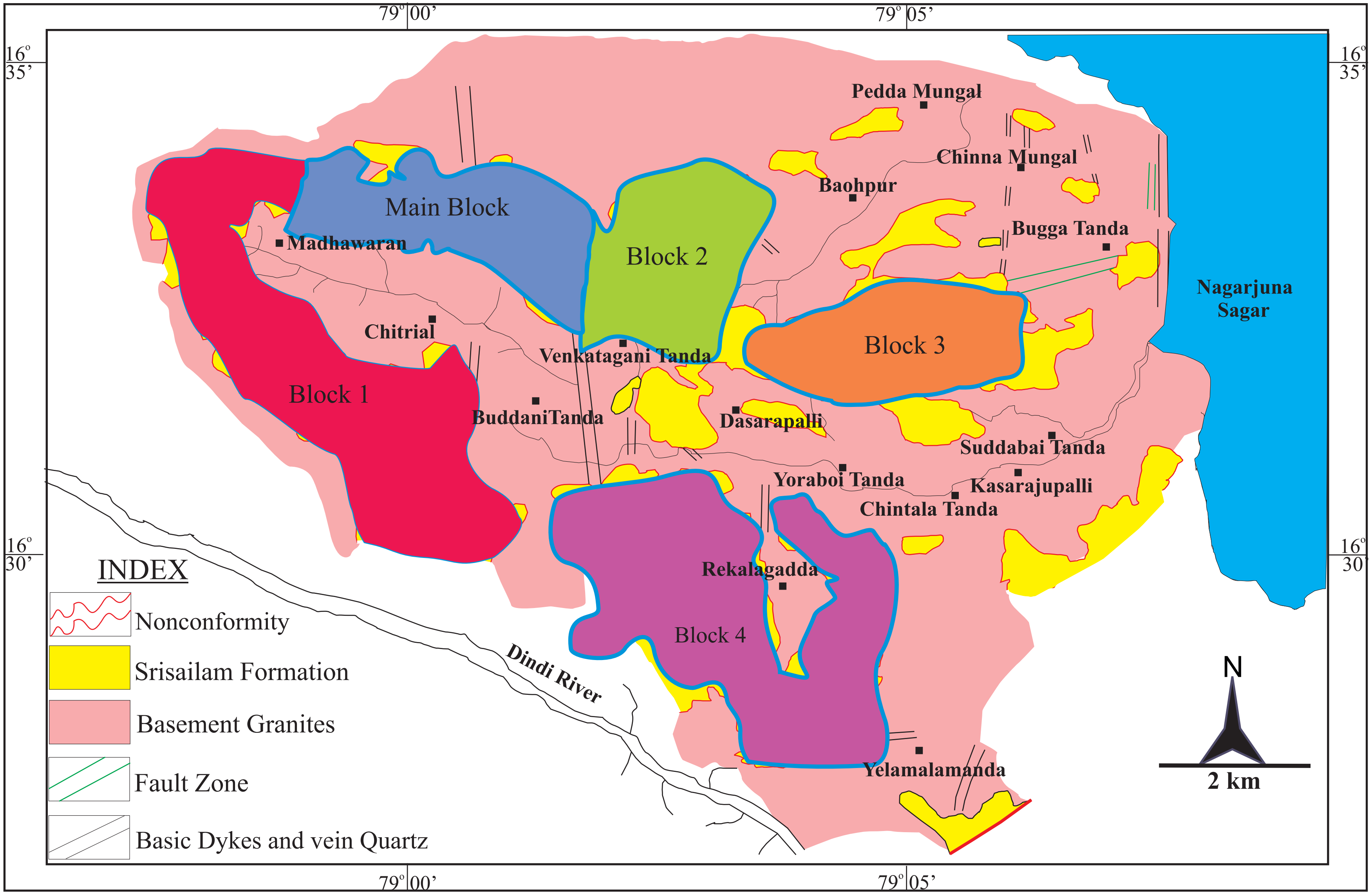

Figure 3.7: Geological map of the Chitrial Outlier, (modified after *Verma et al., 2009* and *Umamaheshwar et al., 2009*) shows five blocks according to uranium concentration.

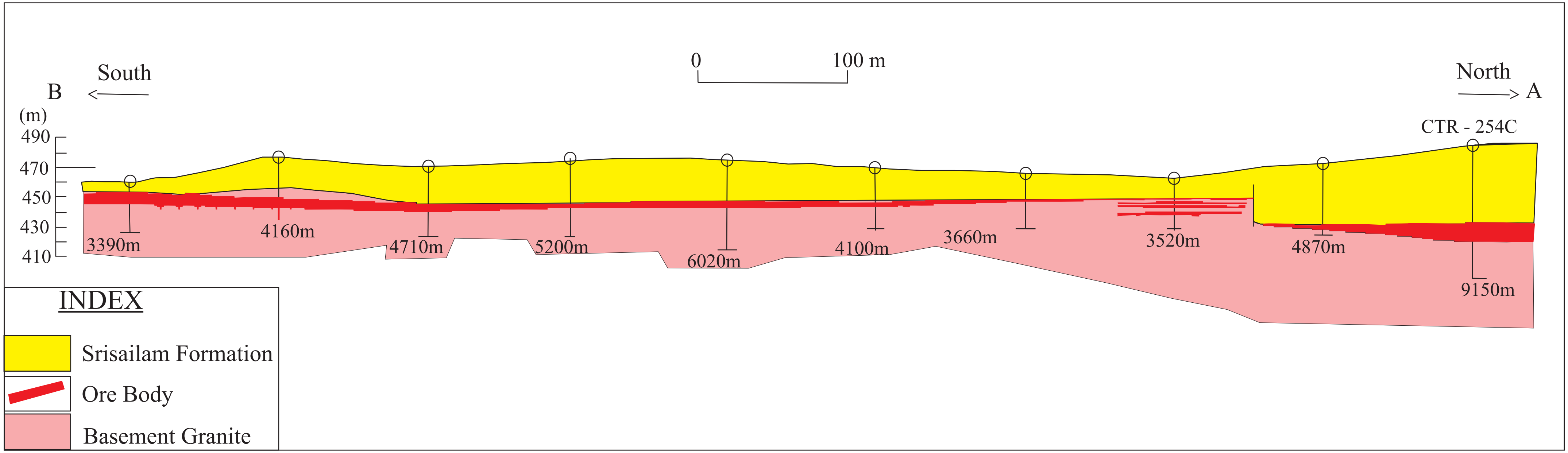

Figure 3.8: Borehole correlation section showing position of Uranium ore in the Chitrial area (modified after *Umamaheshwar et al.,2009*)

Srisailam Formation	Ferruginous Quartzite Shale and Quartzite intercalations Conglomerate / pebbly Quartzite with thin layers of grey shale
Unconformity	
Lower Proterozoic basement	Quartz / Pegmatitic veins Basic dyke Granite

Table. 3.1: Simplified Stratigraphic succession of Chitrial Outlier (after *Verma et al., 2008*)