The Central Indian shield is a collage of two cratonic blocks, the northerly lying Bundlekhand block and the southerly lying Bastar block separated by Narmada-Son lineament or Central Indian Tectonic Zone (CITZ) running nearly east-west. The Bastar craton which is considered to be of Archean age contains granitoids and gneisses. These granitoids and gneisses form the basement for the Proterozoic supracrustal rocks. The supracrustal rocks of the Bastar craton can be conveniently divided into Older (Archean - Paleoproterozoic) supracrustals and Younger (Neoproterozoic) supracrustals. The Older supracrustals (Archean – Paleoproterozoic) are highly deformed and metamorphosed, while the younger supracrustals (Neoproterozoic) of the Bastar craton are undeformed and unmetamorphosed.

The Bastar craton consists of three major Archean - Paleoproterozoic and three Paleoproterozoic supracrustal groups. The Archean - Paleoproterozoic supracrustal groups are (i) the Bailadila Group, (ii) the Bengpal Group and (iii) the Sukma Group in the southern part of the craton, and Paleoproterozoic supracrustal groups are (i) the Sakoli Group, (ii) the Dongargarh Supergroup and (iii) the Sausar Group in the northern part of the craton. The younger supracrustal rocks occur in two major Neoproterozoic basins namely (1) the Chhattisgarh basin and (2) the Indravati basin (Bastar basin) within the Bastar craton.

Among these supracrustal rocks, the Paleoproterozoic metasedimentary rocks (metapelite, quartzite) of the Sakoli basin and the Sausar basin, and Neoproterozoic
unmetamorphosed sedimentary rocks (shale, sandstone) of the Chhattisgarh basin and the Indravati basin have been included in the present study.

The Sakoli Group is composed of supracrustal rocks including mostly metapelite and quartzite with basalt and rhyolite. The Sausar Group comprises of quartzite, pelite and carbonate associations containing stratiform manganese deposits which form the largest manganese reserves in India.

The Chhattisgarh and Indravati basins are two major intra-cratonic sedimentary basins of the Bastar craton containing the Neoproterozoic sediments. The basins are similar in their mixed siliclastic - carbonate lithology, absence of metamorphic overprinting and very low tectonic disturbance. The Chhattisgarh and Indravati basins consist of unmetamorphosed conglomerate, sandstone, shale, limestone, chert and dolomite. Origin of both the Paleoproterozoic and the Neoproterozoic cratonic basins however, is still poorly constrained, though a riftogenic or intra-cratonic origin has been invoked for them.

Occurrence of rock formations in the Bastar craton ranging in age from the Paleoproterozoic to the Neoproterozoic make this region a unique terrain where geological processes operated for a long geological period which is most suited to understand the Proterozoic crustal evolution. The emphasis of the present work is to carry out petrological and geochemical studies of the Neoproterozoic rocks of the Chhattisgarh and Indravati basins of the Bastar craton to know the paleoweathering, source rock composition and tectonic setting. Geochemical studies of Paleoproterozoic metasedimentary rocks of the Sakoli and Sausar basins of the Bastar craton have also been carried out for comparison to know whether there was any change in paleoweathering, source rock composition and tectonic setting through the Proterozoic time in the Bastar craton.

Petrography of sandstones and geochemical studies of terrigenous sediments have long been used to determine the compositions of the provenance, to evaluate weathering
processes and paleoclimate, to qualify the secondary processes such as hydraulic sorting, to model the tectonic setting of the basin and finally to trace the evolutionary history of mantle and crust.

In the absence of available geochemical data of the clastic rocks of the Bastar craton, comparison of the data have been made against the available geochemical data of North American Shale Composite (NASC), Upper Continental Crust (UCC), granite and gneiss of Bastar craton, mafic volcanic rocks of Bastar craton and Paleoproterozoic Kaapvaal pelites of the Kaapvaal craton which share many common conditions with the Paleoproterozoic supracrustals of the Bastar craton.

Petrographic study reveals that the main framework grains of the Paleoproterozoic Sakoli and Sausar pelites are quartz, chlorite, muscovite, biotite, garnet and opaques. The Sakoli and Sausar quartzites are composed of quartz, muscovite, biotite and opaques. The mineralogy of pelites, quartzites and shales has been of less use than the mineralogy of sandstones in determining the provenance since many minerals in such rocks are formed during weathering, diagenesis and metamorphism. Keeping the above consideration in mind, only the Neoproterozoic sandstones of the Chhattisgarh basin and the Indravati basin have been investigated in detail in order to trace out their provenance and tectonic setting.

Modal analysis of the sandstones reveals that the main detrital framework mineral grains of the Chandarpur Group of the Chhattisgarh basin and the Tiratgarh Formation of the Indravati basin include quartz, potash feldspar, plagioclase, rock fragments (mainly chert), micas and heavy minerals. Sandstones of the Chandarpur Group and the Tiratgarh Formation of the Indravati Group are characterized by abundant quartz grains (82.22 % and 88.16 % on average, respectively). According to Folk’s classification (Folk, 1980), the sandstones of the Chandarpur Group and the Tiratgarh Formation are mostly subarkoses, sublitharenites and quartzarenite. Quartz occurs mainly as monocrystalline quartz. Some of these have undulatory extinction. Polycrystalline quartz represented by recrystallized and stretched metamorphic quartz occurs in subordinate proportions. In majority of polycrystalline grains, subgrains with both straight and sutured contacts are
common. Feldspar constitutes 1.87% and 2.02% on average of the framework grains of the Chandarpur Group and the Tiratgarh Formation respectively, and is dominated by microcline. However, plagioclase is also present in minor quantities in some samples. Rock fragments are very few and are dominated by sedimentary lithics (mainly chert). Heavy minerals are rare and are dominated by zircon. These sandstones are generally matrix free. Authigenic quartz, iron oxide and calcite are dominantly cementing material. Quartz cement occurs primarily as overgrowth around detrital grains.

On average, compositions of the Chandarpur Group become more mature in the Kansapathar Formation. The proportion of framework quartz increases from Lohardih Formation (Lower Formation of the Chandarpur Group) to the Kansapathar Formation (Upper Formation of the Chandarpur Group) stratigraphically at the expense of less robust constituents. The chemical data show that SiO₂ increases through time and all major oxides decreases progressively. The variation in modal abundances and the concentrations of CaO, Na₂O and K₂O indicate that alkalis are mainly controlled by the abundance and composition of feldspars. The sandstones are mature because of their low feldspar and negligible lithic fragment content.

Under microscope, the Neoproterozoic shales of the Chhattisgarh basin and the Indravati basin of the Bastar craton display compositional variation from that of typical shale to calcite rich shale. This is best depicted by the abundance of CaO in these shales. Therefore, this allows separation of shale samples into the calcareous shales (the Gunderdehi Formation of the Chhattisgarh basin) at >6 % CaO and the non-calcareous shales (the Tarenga Formation of the Chhattisgarh basin and the Jagdalpur Formation of the Indravati basin) at < 0.3 % CaO.

In comparison to NASC (North American Shale Composite), the non-calcareous shales show enrichment in Fe₂O₃ and K₂O while the calcareous shales show enrichment in CaO and MnO. The non-calcareous shales contain higher concentrations of the most major and trace elements (including REEs) compared to the calcareous shales. The exceptions are CaO, MnO, Sr and Br concentrations as they are higher in the calcareous
shales compared to the non-calcareous shales. Plots of transition elements (Sc, V, Ni, Cr). LILEs and HFSEs (Cs, Nb, U and Zr) vs. Al₂O₃ and K₂O yield linear plots for both the calcareous and the non-calcareous shales. This may suggest that these elements in the calcareous and the non-calcareous shales are housed in the clay minerals. Sr correlates positively with CaO but not with Al₂O₃ or K₂O, thus indicating that Sr are housed in calcite rather than in clay minerals. However, elements like Ba, Y and Ta do not show linear trend against Al₂O₃ and K₂O indicating some accessory minerals other than clay minerals (e.g. allanite for Y and barite for Ba) controlling their abundance.

In contrast, the Paleoproterozoic pelites are characterized by lower SiO₂ (59 %) and higher Fe₂O₃' + MgO (10.41 %) compared to the non-calcareous shales (8.6 %) and NASC. Immobile elements like TiO₂ (0.75 %), Al₂O₃ (22.02 %) and Fe₂O₃' (8.62 %) are enriched in the pelites compared to the non-calcareous shales, calcareous shales and NASC. Mobile elements like Na₂O (0.5 % for the pelites and 0.2 % for the non-calcareous shales) and CaO (0.25 % for the pelites and 0.1 % for the non-calcareous shales) are strongly depleted in the pelites and the non-calcareous shales compared to NASC.

Relative to the Neoproterozoic calcareous and the non-calcareous shales, the Paleoproterozoic pelites are highly enriched in all transition elements especially in Cr (189 ppm), Ni (58 ppm), Sc (21 ppm) and V (100 ppm). In the pelites transition elements like Ni and Co show good positive correlation with Al₂O₃ or K₂O while Cr and Sc do not correlate with Al₂O₃ and K₂O. Most of the LILE and HFSE (e.g. Th, U, Rb, Sr) in pelites show good positive correlation against Al₂O₃ and K₂O indicating mica minerals (phyllosilicate) control on their contents.

In chondrite normalized REE plot (Sun and Mc Donough, 1989), both the calcareous and the non-calcareous shales show highly fractionated patterns with LREE enrichment having (La/Yb)n ratio of 18 for non-calcareous shales and 7 for the calcareous shales, flat HREE with (Gd/Yb)n ratio of 1.9 for the non-calcareous shales and 1.4 for the calcareous shales, and negative Eu anomaly (0.65 for the non-calcareous
shales and 0.8 for the calcareous shales). The chondrite normalized LREE pattern of the pelite Sample No. DS-524 is also fractionated but less fractionated than that of the non-calcareous and calcareous shales with LREE enrichment having (La/Yb)n of 8.86 and flat HREE with (Gd/Yb)n of 1.83 and small negative Eu anomaly (Eu/Eu* = 0.80).

The major element composition of the sandstones of all the three formations of the Chandarpur Group does not show much variation. In general the SiO₂ concentration is high (avg. 92.96 wt. %) in all the sandstones of the Chandarpur Group and the Tiratgarh Formation. On the sandstone classification schemes of the Heron (1988) and Pettijohn et al. (1972), the sandstones are mostly sublitharenite, subarkose and arenite.

Relative to NASC, the sandstones and quartzites are depleted in major, trace elements including REE except for SiO₂, Na₂O, Co and Zr. Relative to the sandstones, quartzites have higher concentration of Al₂O₃, Na₂O and K₂O, Cr and Co. The transition elements (like Cr and Co) and the LILEs and HFSEs (like Rb, Cs, Sr, Th, U, Nb, Y and Zr) are higher in quartzites compared to sandstones.

Plots of transition elements (like Sc, Cr, Ni), LILEs and HFSEs (like U, Cs, Th, Rb, Ba and Ta) against Al₂O₃ and K₂O yield linear plots for both the sandstones and quartzites. However elements like Zr, Y, Nb do not show linear trend against Al₂O₃ and K₂O indicating some accessory minerals (e.g. allanite for Y, zircon for Zr) other than feldspar and mica to be controlling their abundance in the sandstones and the quartzites.

In chondrite normalized plot both the sandstones and the quartzites show highly fractionated REE patterns, with LREE enrichment having (La/Yb)n of 12.5 for sandstones and 12 for the quartzites, flat HREE patterns with (Gd/Yb)n of 1.56 for sandstones and 1.42 for the quartzites and a significant negative Eu anomaly (0.67 for the sandstones and 0.47 for the quartzites).

To identify the provenances and tectonic setting, the recalculated parameters of modal data were plotted on standard ternary diagrams given by Dickinson and Suczek.
(1979). On the QmFLt, QtFL and QmPK plots, the sandstone samples from all the three formations of the Chandarpur Group of the Chhattisgarh basin and the Tiratgarh Formation of the Indravati basin plot in the intra-cratonic field. On the SiO$_2$ vs. K$_2$O/Na$_2$O ratio diagram of Roser and Korsch (1986), all the Paleoproterozoic pelite and quartzite samples, and the Neoproterozoic sandstone and non-calcareous shale samples plot exclusively in the passive margin field (PM). The SiO$_2$/Al$_2$O$_3$ vs. K$_2$O/Na$_2$O plot of Maynard (1982) for the Paleoproterozoic pelite and quartzite samples, and the Neoproterozoic sandstone, calcareous and non-calcareous shale samples also suggest that the sediments were deposited in passive margin setting (except for the one pelite sample which falls in continental island arc field (CIA).

The geochemical tectonic setting discriminating parameters of Bhatia (1983), Fe$_2$O$_3^{1}$ + MgO, TiO$_2$, Al$_2$O$_3$/SiO$_2$, K$_2$O/Na$_2$O and Al$_2$O$_3$/(CaO + Na$_2$O) of the sandstones and quartzite samples are comparable with that of passive margin (PM). The higher K$_2$O/Na$_2$O and Al$_2$O$_3$/(CaO+Na$_2$O) ratios of the non-calcareous shales and the pelite samples are also comparable with passive margin setting (PM).

On the Th - Sc - Zr/10 diagram all the sandstone samples of the Neoproterozoic Chhattisgarh basin and the Indravati basin plot near passive margin while the calcareous and the non-calcareous shale samples of the Chhattisgarh basin and Indravati basin plot near the active continental margin and continental arc fields. The pelite and quartzite samples of the Paleoproterozoic Sakoli and Sausar basins show a lot of scatter between active continental margin (ACM) and continental Island Arc (CIA). The wide scattering of the non-calcareous shale, pelite and quartzite samples between active continental margin and continental arc field on the Th-Sc-Zr/10 plot may be due effect of sorting.

Thus, it is inferred that intra-cratonic tectonic setting existed for both the Paleoproterozoic and the Neoproterozoic basins and in other words suggest stability of the Bastar craton during the Paleoproterozoic and the Neoproterozoic time. This study strengthens the stable intra-cratonic origin of these Paleoproterozoic and Neoproterozoic basins of the Bastar craton.
The enrichment of immobile elements like SiO₂, Al₂O₃, TiO₂, Rb and Ba and depletion of Na₂O, CaO and Sr in the studied samples especially in the Neoproterozoic non-calcareous shales and the Paleoproterozoic pelites suggests moderate to intense chemical weathering. The average CIA values of the Neoproterozoic non-calcareous shales (72.40) and the Paleoproterozoic pelites (79.06) are higher than that of NASC (57.12). Thus, CIA values of the Neoproterozoic non-calcareous shales and the Paleoproterozoic pelites suggest moderate to intense chemical weathering for these rock samples. Such an inference is also supported by the average trend of these sediments on A - CN - K diagram, which is defined by the chlorite and muscovite - illite end members. However, the average CIA values of the Paleoproterozoic quartzites (55.66) and the Neoproterozoic sandstones (67.50) are lower than the Paleoproterozoic pelites and the Neoproterozoic non-calcareous shales. The lower CIA values of the quartzites and sandstones probably do not reflect the general weathering conditions of the source region, but it may be due to sedimentary sorting effect. Moderate to intense chemical weathering of source rocks of the Paleoproterozoic pelites, and the Neoproterozoic non-calcareous shales and sandstones is also indicated by their high average plagioclase index of alteration values (PIA >80).

On the K₂O - Fe₂O₃ - Al₂O₃ ternary diagram most of the samples plot near NASC and some samples also plot between NASC and residual clays. The samples on this diagram fall along a trend defined by chlorite - illite and muscovite end members. Both the A - CN - K and Fe₂O₃ - K₂O - Al₂O₃ plots indicate moderate to intense chemical weathering in the provenance. This is further demonstrated by the ratios of K/Rb and Th/U ratios of the Paleoproterozoic pelites and quartzites, and the Neoproterozoic shales (both the non- calcareous shales and calcareous shales) and sandstones of the Bastar craton.

NASC normalized elemental concentrations of Paleoproterozoic pelites and quartzites, and Neoproterozoic shales and sandstones indicate that the sandstones, quartzites and shales (calcareous and non-calcareous shales) of the Bastar craton are depleted in mafic elements like Ni, Cr, Sc, Fe₂O₃, MgO, and TiO₂ while the
Paleoproterozoic pelites are enriched in mafic elements and show close similarity in these elements with the Paleoproterozoic Kaapvaal pelites of the Kaapvaal craton (derived from mafic source). This comparison indicates that the pelites were derived from a mafic source and the sandstones, quartzites and shales (calcareous and non-calcareous) were derived from a felsic source.

Most of the elemental concentrations of the Neoproterozoic sandstones are lower than those in NASC due to higher quartz content. The elemental concentrations of the Neoproterozoic calcareous shales are also lower than those in NASC due to calcite dilution. But when certain key trace elemental ratios like Eu/Eu*, Th/Sc, La/Sc, Th/Ni, Th/Cr, La/Ni and La/Cr of these quartz rich sandstones and of the calcareous shales have been plotted for quartz rich sandstones against SiO$_2$ (wt. %) and for the calcareous shales against CaO (wt. %), it is found that these elemental ratios are not much affected in the calcareous shales by calcite dilution and in sandstones by higher quartz content.

Certain key elemental ratios (incompatible/compatible) like Th/Sc, La/Sc, Th/Ni, Th/Cr, La/Ni and La/Cr of sandstones, shales, quartzites and pelite sample were normalized with those of the upper continental crust (UCC). It is observed that all the elemental ratios of the Neoproterozoic sandstones, shales (calcareous and non-calcareous shales) and the Paleoproterozoic quartzites are similar to UCC and show small deviation from UCC, suggesting all these rocks were derived from source similar to UCC. However, the Paleoproterozoic pelite sample show strong depletion in La/Sc, Th/Ni, Th/Cr, La/Ni and La/Cr ratios compared to UCC indicating a less differentiated source than UCC for the pelite.

The Ni-Cr and Th/Sc vs. Sc diagrams further suggest that Paleoproterozoic pelites were derived from mafic source and Neoproterozoic shales and sandstones and the Paleoproterozoic quartzites were derived from felsic source. The felsic sources were identified to be granite and gneiss of the Bastar craton.
The chondrite normalized REE diagram shows that REE patterns of the sandstones, the quartzites and the shales (calcareous and non-calcareous) are highly fractionated and there are no systematic variation in the REE patterns of the sandstones, quartzites and shales (calcereous and non-calcereous). The REE patterns and Eu/Eu* of the calcereous, non-calcereous shales and sandstones are similar to the granite (Eu/Eu* = 0.39) and the gneiss (Eu/Eu* =0.65) of the Bastar craton and do not match with the REE patterns of Archean mafic volcanic rocks of the Bastar craton. This further supports the felsic source for the Neoproterozoic sandstones and shales (calcereous and non-calcereous) of the Bastar craton.

In comparison to NASC, the pelite sample has lower REE abundances, and lower ratios of (La/Yb)n = 8.86 and (Gd/Yb)n = 1.83 and a small negative Eu anomaly (Eu/Eu* = 0.80). The REE pattern of the Paleoproterozoic pelite of the Bastar craton is clearly different from that of the Neoproterozoic sandstones, shales (calcereous and non-calcereous) and the Paleoproterozoic quartzites. The REE pattern of the pelite sample shows less fractionated trend than those of the sandstones, quartzites and shales (non-calcereous and calcereous).

The overall petrological and geochemical evidence indicates that the source rocks for the Neoproterozoic shales (calcereous and non-calcereous shales) and sandstones, and Paleoproterozoic quartzites were felsic in nature and the source rocks have been identified to be granite and gneiss of the Bastar craton. However, the source rocks for the Paleoproterozoic pelites have been identified to be the mafic volcanic rocks of the Bastar craton. The data also show petrological and geochemical similarities between the Neoproterozoic sandstones of the Chandarpur Group of the Chhattisgarh basin and the Tiratgarh Formation of the Indravati basin and thus indicate homogeneity in the source rock composition during the Neoproterozoic time and also indicate that the sediments for the Neoproterozoic Chhattisgarh and Indravati basins have been derived from similar sources i.e. granite and gneiss of the Bastar craton, and minor amount of detritus may have been derived from older sedimentary/metasedimentary successions of the craton which is consistent with petrography and paleocurrent studies. In contrast, the
Paleoproterozoic pelites and quartzites of the Sakoli and Sausar basins suggest heterogeneity in the source area. The Paleoproterozoic pelites of the Sakoli and Sausar Groups are enriched in mafic components while the Paleoproterozoic quartzites from the Sakoli and Sausar Groups are enriched in felsic components. This may be due to hydraulic sorting, as it sorts different source components into different grain size class. Thus, this is advantageous to use both pelites/shales and quartzites/sandstones, so as to delineate all source end members particularly the mafic end members and felsic end members respectively.

Thus, the present study shows that there is strong evidence to suggest a change in the upper crustal composition during Proterozoic in the Bastar craton and also there is ample evidence to suggest that the Paleoproterozoic exposed crust was less differentiated compared to the Neoproterozoic crust. The overall mineralogical and geochemical characteristics i.e. mixing of two end member source compositions exhibited by the Paleoproterozoic pelites (more mafic) and quartzites (felsic) relative to total felsic composition of the Neoptoterozoic shales and sandstones suggest that the composition of the source region of the Paleoproterozoic supracrustal rocks represented a transitional stage from mixed (mafic + felsic) in the Paleoproterozoic to entirely felsic in the Neoproterozoic in the unidirectional evolution of the Proterozoic continental crust of the Bastar craton. However, the geochemical characteristics do not indicate any change in tectonic setting from the Paleoproterozoic Sakoli and Sausar basins and the Neoproterozoic Chhattisgarh and Indravati basins of the Bastar craton. It is inferred that the intra-cratonic tectonic setting existed for both the Paleoproterozoic Sakoli and Sausar basins and the Neoproterozoic Chhattisgarh and Indravati basins and in other words suggest stability of the Bastar craton during the Paleoproterozoic and Neoproterozoic time. This study also strengthens the stable intra-cratonic origin of these Paleoproterozoic and Neoproterozoic basins of the Bastar craton using the petrology and geochemistry of the Paleoproterozoic and the Neoproterozoic supracrustal rocks of the Bastar craton. The relationship among alkali and alkaline earth elements, CIA, PIA, Th/U and K/Rb ratios indicate that source area in the Bastar craton during the Proterozoic was affected by moderate to intense weathering history.