An insight into the subsurface geology of the Andaman Islands using clasts ejected through the mud volcanoes

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Abstract: Mud volcanism is an important phenomenon at convergent margins that provide windows to explore shallow level subduction zones processes, geochemical recycling and sub-surface stratigraphy [1, 2]. Active mud volcanoes are reported from the Baratang and Diglipur regions of Andaman Islands, located at the Indian and Burma Plate convergent margin [3]. In this work, an attempt has been made to establish the sub-surface stratigraphy of the region by studying the geochemical and Sr-Nd isotopes of approximately forty rock clasts ejected with the mud breccia through the mud volcanoes. These clasts exist in various shapes and sizes and are very complex mixture of material derived from successions within Andaman accretionary prism ranging in age from late Cretaceous to Oligocene. Based on this study, it is recognized that most of the clasts from Andaman mud volcanoes are originated from the underlying formations of the Mithakhari Group. There are minor occurrences of clasts from the basal Ophiolite Group and the overlying Andaman Flysch Group as well. The reconstructed stratigraphy suggests that there has been deep-sea depositional environment until the depositions of lower formations represented by clasts of Type-I, IV and V. This was followed by shallowing of the (trench-slope) basins in which the formations for Type-VIII, III and II clasts were deposited. A model proposed for the mud volcanism suggested that the mud volcanoes of Andaman extract mud breccia from the chaotic (tectonic) mélange occurring at the depth of 6-7 km, methane formation occur at the depth range of 8.2-12.2 km whereas water is originated from the depth of ~9 km within the Andaman prism. The studied rock clasts have comparatively shallower origin from the host/wall rock formations and are picked by the mud breccia while travelling through the plumbing system. The faults and fractures in the

accretionary prism provide pathways to this composite mixture to erupt out to the surface as mud volcanoes.

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Fig. 1: (a) A map of the Indian sub-continent showing location of the Andaman Islands in the north-eastern Indian ocean (b) A geological map of the Andaman showing distribution of various stratigraphic units with mud volcanoes sites (Baratang & Diglipur) and major fault systems (c) A detailed geological map of the Baratang Island with locations of visited and studied mud volcanoes (M-1 to M-6) (d) A detailed geological map of the North Andaman with locations of studied mud volcano (M-7 & M-8).

Zoned crystal records of open magma chamber fractionation, mafic recharge, remobilisation of crystal mush zone in LIPs: Insights from the lamprophyres and dolerites of end-Cretaceous (ca. 66 Ma) Phenaimata alkaline igneous complex, NW India

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The end-Cretaceous (ca. 66 Ma) Phenaimata alkaline igneous complex, associated in space and time with the Deccan Large Igneous Province (LIP) in Western India, consists of bimodal (tholeiitic to alkaline) differentiated plutonic to volcanic igneous rocks. Such alkaline complexes with diversified rock assemblages are the outcomes of the complex magmatic processes. Thus in order to investigate magma reservoir processes beneath the Phenaimata alkaline complex and what are their effect on the chemistry of the emplaced rocks we carried out the detailed mineralogical and petrological study of the lamprophyre and dolerite dykes of the complex. The detailed textural and petrographic study reveals that the two lamprophyre dykes intruding basalt/olivine dolerites (camptoite-I) and gabbro (camptonite-II) consist of numerous crystal cargos of various minerals (pyroxene, amphibole and biotite) with varied type of zoning but differ in their liquidus assemblages and crystal size distribution. Whereas, the dolerites are mostly dominated by the liquids phases baring the olivine antecrysts, created during the earlier stages of host gabbro formation. The normal and reverse compositional zoning of pyroxene and amphibole from the lamprophyres shows that their parental magma initially experienced a closed system fractionation and was subsequently replenished by a newer flux of magma leading to open system fractionation. This recharge leads to disaggregation and remobilisation of the initially formed macrocrysts

from the mush zone which is evident from the distinct corroded margins of the normally zoned grains and resorbed inner cores of the reversely zoned crystals. This crystal laden replenished magma subsequently evolved to form camptonite-I. Later on, the successive lateral spreading of the newly generated magma increased its buoyancy to rise through the smaller crustal chamber (with biotites) to generate camptonite-II. Thus through this study we demonstrate that the diverse complex magmatic chamber processes significantly influence the ultimate composition of the diverse rocks and are pivotal in the formation of the alkaline complexes associated with the flood basalt volcanism in Large Igneous Provinces.

Bridgmanite in shock-melt veins of Katol L6 chondrite

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The physico-chemical, electrical, and mechanical properties of bridgmanite have long been of keen interest to scientists as it is the most abundant mineral phase in the planet Earth [1]. Various laboratory experiments have been done to establish the behaviour of bridgmanite in vastly different scenarios [e.g., 2]. Although, such studies are incomplete and need to be validated using the natural specimens of bridgmanite. However, natural occurrences are rare and consist of back transformed, low-pressure phases like pyroxene and glass instead [3]. Fortunately, shocked meteorites have been the primary natural source for most of the high-pressure phases discovered till date. Bridgmanite is no exception and was discovered in shocked Tenham L6 chondrite [4]. However, these natural occurrences of bridgmanite are compositionally different than terrestrial bridgmanite. Here we report the first natural occurrence of Fe-bearing aluminous bridgmanite present in the shock-melt veins of Katol L6 chondrite that matches the bridgmanite composition predicted for Earth's mantle [5]. The Katol bridgmanite coexists with majorite and metal-sulfide intergrowth. Textural observations and comparison with laboratory experiments suggest that the Katol bridgmanite

formed at pressures of ~23 to 25 gigapascals directly from the chondritic melt generated by the shock event.

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Insights into the subduction zone processes and generation of arc magmas in the Barren and Narcondam Islands, Andaman subduction zone: A review

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Abstract

Magma generated in a subduction zone is a key to understand the growth of the continental crust, crust-mantle recycling and slab-mantle interface related processes. Incorporation of the different subduction components into the mantle wedge modifies the mantle and its extracted melts. However, contribution of different subduction components in the source of the arc rocks remains controversy in different part of the world. The lavas in the Barren and Narcondam Islands have been generated in oceanic subduction setting in the Andaman Sea. In this study, we compiled the available geochemical and isotopic data in the Barren and Narcondam Islands and review for better understanding the relative contribution of different subduction components to generate arc magmas and the slab-mantle interface related processes in subduction zone. The variation in Ba/Th and Th/Nd in the lavas of the Barren and Narcondam Islands provides a hint for influx of fluids derived from the subducting slab and sediment melt in the source. Lu/Hf ratios in these lavas display negatively correlated changes with Th/Nd suggesting incorporation of melts derived from both pelagic and terrigenous sediments in their source. We also carried out trace elements model to understand the source of these lavas. Four steps model have been conducted; 1) dehydration of altered oceanic igneous rocks (AOIR) and subducted siliciclastic sediments (SSS), 2) melting of the SSS, 3) then depleted-MORB mantle (DMM) has been metasomatised by influx of these fluids and sediment melt and 4) the metasomatised mantle has undergone partial melting. The model result suggests that the trace element abundances in these lavas, except Nb and Ta, can be explained by 5%-20% of melts extracted from the metasomatised mantle source. However,

high depletion in Nb and Ta in the N-MORB normalized trace elements' patterns and very low Nb/Th in these lavas can be explained by fractionation of rutile (~10%) from the fluxed sediment melt. Further, three mixing trends have been constructed by incremental addition of fluids (i.e., the AOIR- and SSS-derived fluids) and sediment melt to the Indian-MORB to quantify the relative contribution of the different subduction components in the source of these arc lavas. Based on this mixing model, it is confirmed that ~2% of sediment fluids, ~1% of sediment melts and ~8% of AOIR derived fluids have been contributed to the source of the Barren Island lavas, whereas the source of the Narcondam Island lavas has been incorporated by ~8% of sediment fluids, ~10% of sediment melt and ~ 10% of AOIR fluids. These geochemical models also indicates that the slab derived fluids have incorporated dominantly in the source of these lavas but influx of sediments melt were higher in the source of the Narcondam Island compared to that of the Barren lavas. This study concludes that varying proportions of melt- and fluid-phases released from the subducting slab due to progressive degrees of metamorphism in the subducting slab at different depths can be recorded in the arc magmas.

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Geochemical Characterization of Meso-Proterozoic Carbonates from Pindwara- AbuRoad Belt, Sirohi District, Rajasthan

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Abstract

Carbonate metasediments on the western margin of the Delhi Supergroup from the Sirohi region show significant variations in the carbon and oxygen isotope values. The average positive value of $\delta^{13}C$ (from 2 to + 4.96%) represents the Meso–Neoproterozoic transition (from, 1.25 to 0.85 Ga), a period characterized by globally high positive $\delta^{13}C$ value. The carbonates from the Pindwara–AbuRoad Belt (PARB) along the western part of Delhi Supergroup having $\delta^{13}C$ values between +3.0 and +4.6‰ are considered of late Mesoproterozoic age, that is well-matched with the global trends recording moderate excursions in $\delta^{13}C$ between +2 and +4‰. The adjacent Sirohi Group carbonates show a noticeable difference in heavy carbon isotopic values that range between −3.5 and +1.3‰. This difference in carbon isotope values suggests that the Sirohi Group carbonate metasediments were not coeval with that of the proximally associated PARB metasediments and their stratigraphic status must be distinct.

The positive carbon isotope values have been linked to organic carbon burial coupled with an increase in oxygen levels whereas negative values have been linked with glaciation phases during the Neoproterozoic age that is followed by marine sedimentation.

The present study emphasizes petrology, mineral chemistry, and bulk rock geochemistry of some selected carbonate rocks from the western margin of the South Delhi Supergroup that yield distinct mineralogical and geochemical characters of carbonates suggestive of admixture of different detrital phases. As a whole, the study of

these metasediments may comment on the paleo-depositional environment of these carbonates along with their protolith, provenances, and relation with global events. Therefore the present study was an attempt to correlate the carbonate metasediments from the western margin of Delhi Supergroup with that of the adjacent Sirohi group under the lights of conventional geological investigations along with isotopic characters.

Keywords: Carbonate, Pindwara–AbuRoad Belt, Meso–Neoproterozoic transition, positive carbon isotope value.

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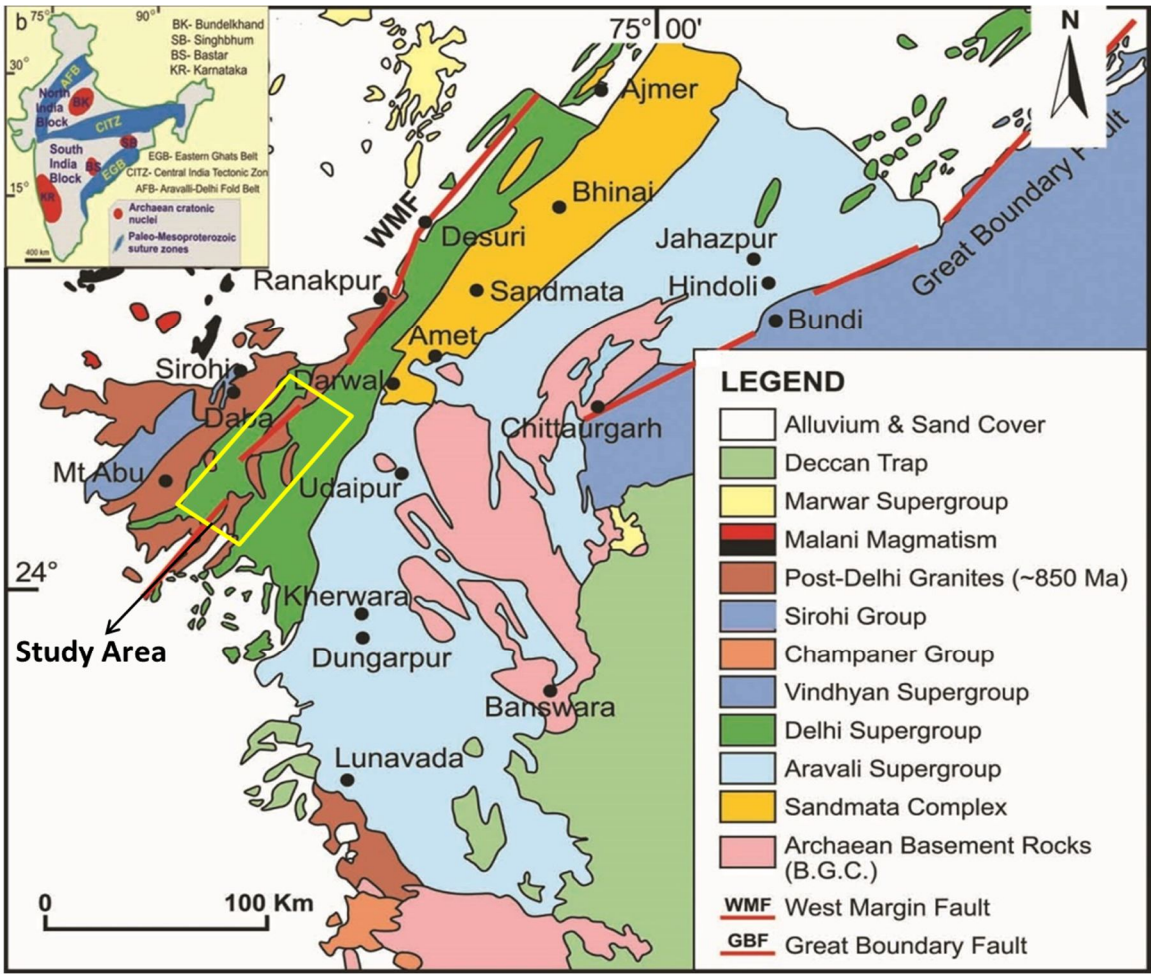

Figure 1: Generalized Geological Map of Rajasthan (modified after Roy & Jakhar 2002) with Marked Study Area

Noble gas in interior of rocky planets

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Introduction: Noble gases are perhaps the most important tracers of the history of planets atmosphere and its interaction with the solid planet. Terrestrial planets (Mercury, Venus, Earth, and Mars) are believed to have formed by the accretion of early solar system objects that are represented by primitive meteorites [1].Terrestrial planets are differentiated and they have three layered structure: a metallic core, a silicate shell (mantle and crust). The present work was aimed at understanding the noble gases isotopic systematic of the interior of Venus and Mercury for that we utilize the data set of basaltic rocks of Earth and Mars.

Methodology: In the present study, we utilize the noble gas abundances in Earth and Mars. Noble gas abundances in bulk samples of Mid Ocean Ridge Basalt (MORB) and oceanic island basalts (OIB) (mantle of Earth) and meteorite Chassigny (mantle of Mars) are used and concentrations of trapped noble gases were estimated.

Discussion: The concentrations of ^{36}Ar, ^{84}Kr and ^{132}Xe in the MORB, OIB and Chassigny are differ to the primitive chondrites. The concentrations of trapped noble gases in MORB, OIB [2] are dissimilar to that in Chassigny [3]. These results suggest that the concentration in the two planetary bodies Earth and Mars are depleted as compared to starting material of primitive chondrites. A major link in understanding the elemental and isotopic concentration of noble gases in interior of Mercury and Venus is still poorly known. Mercury an airless body, the noble gas study for the tenuous atmosphere on the surface is limited to ultraviolet spectroscopy and isotopic compositions have not been determined, except for a single ^{40}Ar/^{36}Ar ratio of approximately 10 [4]. The isotopic ratios of neon and argon in Venus atmosphere are unique. Neon isotopes in Venusian atmosphere are similar to the solar wind however the ^{40}Ar/^{36}Ar is of primordial nature [5].The distinct elemental ratios of MORB, OIB, chassiginy that represent the interior of differentiated objects suggesting a different degassing history of the differentiated parent body. Since there is no direct sample available from the interior of the Mercury and

Venus, hence based on the above study we can infer that there could be a distinct component and different degassing history in the remaining terrestrial objects.

Conclusion: The differences between the Earth and Mars in the abundance pattern, two of them are depleted in heavy isotopes with respect to carbonaceous chondrites. The measurement of the heavy isotopes in Venus and Mercury will allow to understand the volatile evolution of the respective parent body. Future exploration of Mercury and Venus combined with Earth and Mars help us to improve understanding volatile evolution in the rocky objects in the extra-solar planets.

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Crust-mantle interaction and crustal reworking during the Neoarchean: a precursor to cratonization of the western Dharwar craton

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A combined field, petrographic, whole-rock elemental and Sr-Nd isotopic study of three Neoarchean granitoids, viz., Chitradurga, JN Kote and Hosadurga that intruded the Chitradurga Greenstone Belt (CGB) tells us about their petrogenesis and the extent of crustal reworking in WDC in the Neoarchean. The plutons are composed of porphyritic and equigranular and medium to coarse grained granites and a dark grey graniotid of trondhjemitic composition. Geochemically, the granites make two distinct group, a dark grey phase of Chitradurga, which commonly includes mafic enclaves of basaltic composition, with lower SiO_2 and higher Fe_2O_3, TiO_2, MgO, CaO & P_2O_5 and higher REE content than the pink and light grey granites.

The granites are highly potassic, weakly peraluminous (A/CNK <1.1) and alkali-calcic to calc-alkalic akin to I-type granites. The trondhjemite has lower K_2O/Na_2O (<0.5) ratios similar to Tonalite-Trondhjemite-Granodiorite (TTG) suite, but lower Mg# (11-18%), Sr/Y (2-8) and negative Eu & Sr anomalies and slightly fractionated HREE pattern (1.2-2.4), which are unusual in classical TTGs, suggesting their derivation dominantly by crustal melting. The low Cr, Ni & Mg# (10-40%), higher K_2O/Na_2O and prominent negative Eu & Sr anomalies of granites indicate that they are formed from crustal sources at moderate depths. Trace element modeling shows that a low degree partial melting of TTG sources can explain the elemental pattern of Hosadurga granite and pink and grey granite of Chitradurga. The negative epsilon Nd values (-1.6 to -7.6 at t = 2.6 Ga) and model ages (T_{DM} = 3.1-3.7 Ga) also suggest crustal sources.

The heat related to the emplacement of volcanic traps of Dharwar Supergroup could possibly triggered crustal melting in the Neoarchean. Mixing with this mafic melt may have involved in the formation of some of these granites. The wide range of epsilon Nd values could be resulted from this mixing or due to the heterogeneity of the source. Reworking of the TTG crust and formation of these potassic granitoids were precursor to cratonization of the Dharwar craton by end of the Neoarchean.

Evidence of Holocene Palaeo-flood records from the sediments of the Great Rann of Kachchh, Western India

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Abstract

The Great Rann of Kachchh which barely lies above the sea level (Gupta, 1975, Glennie and Evans, 1976) provides a rare opportunity to understand the land-sea and climatic interaction during the late Quaternary (Glennie and Evans, 1976 ,Tyagi et al., 2012; Ngangom et al, 2012). In this study an attempt has been made to reconstruct the sub-surface lithostratigraphy from a 46.5m core raised near the proximity of Nara river close to the Allahbund scarp (N 24˚ 10` 00``and E 69˚ 12` 00``) in order to ascertain temporal changes in nature and magnitude of sediment aggradation in the western Great Rann. The textural attributes of the core sediment show dominance of micaceous sand with fining upwards characteristic. A total of six such units have been identified implying that Nara river witnessed six flood events of increasing magnitude in a core of 46.5 m which is dated early to mid-Holocene. Climatically the major flood couplets are dated to early Holocene strengthened Indian Summer Monsoon (ISM) which progressively declined towards the mid-Holocene. Interestingly, a significant decline in ISM strength is inferred based on frequent occurrences of oxidizing layers in the core after the mid-Holocene which speculatively assigned the beginning of the late Holocene aridity (4.2 ka) and persisted until the recent times.

Key Words: Great Rann, sub-surface lithostratigraphy, palaeo-floods, core sediments

Minimization of the effect of Down-Hole Fractionation (DHF) in age calculation for Zircon mineral using LA-MCICPMS

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Since the development of LA-ICPMS or LAMCICPMS system, analytical methods of precise Zircon geochronology have been reported with LASER spot size in the range of 20 to 60 micron. This spatial resolution has two main drawbacks. First, this spatial resolution using LAMCICPMS may hit two zones and give the mixed age and important information about the two distinct activities is distorted. Secondly this spatial resolution is unable to date the small rim or very tiny zircon grains which is having thickness lesser than the 20 micron LASER spot. If one goes with higher spatial resolution, the accuracy and precision is degraded due to down-hole fractionation (DHF) which is due to difference in the matrix of standards and decrease in the signal due to small volume is transport to ICP. Therefore existing challenge in this field is to minimize the effect of down hole, matrix effect and improvement in sensitivity of mass spectrometer for spatial resolution better than 20 micron. In this study, an attempt is made to minimize the effect of the DHF to achieve good accuracy and precision for smaller spot size (≤20µm). Three different zircon standards (91500, GJ-1 and Polešovice) were measured for 20, 15 and 8 µm. Zircons were ablated for 30 seconds with 0.5 sec integration time. Effect of the DHF is increased with decrease in the spot size because of the decrease in the signal intensity. In order to minimize the effect of

the DHF for smaller spot size, ablation time is reduced and age is re-calculated for 15, 20 and 25 sec. It has been observed that the accuracy and precision is improved with decrease in the ablation time for the smaller spot as well. The figure of merit is within ~2% error limit for small ablation time.

Physical volcanology of the Pavagadh rhyolites, northern Deccan Traps: Stratigraphic, structural, and textural record of explosive and effusive eruptions

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ABSTRACT

Mount Pavagadh (840 m) in the northern Deccan Traps, India, is mainly composed of mafic lava flows (picrites, ankaramites, mugearites, basalts) and capped by rhyolites. Rhyolites also found at lower elevations, on and around the mountain, are thought to represent blocks of the eroded upper rhyolites or local eruptions in situ. Although the Pavagadh sequence has been studied for 150 years, the stratigraphy, structures, textures, and physical volcanology of the Pavagadh rhyolites have been poorly documented, and are discussed here at length. The upper rhyolite sequence contains tens of non-welded, crystal-bearing, glass- and pumice-rich ash beds of 47 m total thickness. These represent a primary fallout ash succession derived from distant Plinian eruptions, possibly corresponding with massive ignimbrite deposits recently recognised in Saurashtra several hundred kilometers to the southwest. The fallout ash succession is overlain by a 50 m thick lava flow showing well-developed flow banding and folding, basal and upper breccias, and a local basal vitrophyre. The lava flow is overlain by an ignimbrite with a basal vitrophyre, both these units showing excellent vitroclastic textures. The upper rhyolites thus represent alternating explosive-effusive-explosive eruptions. The lower-level rhyolites in the area, showing intense rheomorphic deformation in outcrop but lacking vitroclastic textures, are probably also lavas. However, they are not blocks of the eroded upper rhyolite lava flow but from separate eruptions. The Pavagadh rhyolites were probably far more

laterally extensive than their present outcrops, with a minimum original volume of 9 km^3; their source areas remain unknown. Geochemical and geochronological work on the Pavagadh rhyolites is needed, in the stratigraphic and volcanological context provided here, to understand their petrogenesis and potential relationship with the Cretaceous/Palaeogene (K/Pg) boundary mass extinction.

An appraisal of ground failure and hydrogeological changes associated with the 28 April2021, M w =6Sonitpur earthquake, Assam, India using field evidences and InSAR measurements

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ABSTRACT

Widespread damage and coseismic ground disturbances are generally associated with large magnitude and/or shallow focus earthquakes. Surprisingly, a deep focus (34km),moderate magnitude earthquake (M_w=6) occurred near the Kopili Fault Zone at Sonitpur district, Assam, India on 28 April 2021 created intense ground shaking and extensive damage along the Brahmaputra valley. We undertook a field survey within a day after the earthquake and carried out Interferometric Synthetic Aperture Radar (InSAR) analysis to map coseismic ground deformation features. Our field survey revealed extensive liquefaction features and several coseismic ground cracks at the alluvial fan of the Brahmaputra River. InSAR analysis revealed a sinistralslipof~60mm along an NNW-SSE oriented previously unmapped fault. Field investigations revealed coseismic hydrological changes including sudden rise and fall in water level by 0.3 to0.5 m followed by injection of sand materials up to a thickness of 1.25 m in dug wells and appearance of water in seasonally dried river channels and ponds. Interferometric coherence analysis during pre, co and post seismic periods further confirmed the co-seismic surge in water at five major tributary rivers of the Brahmaputra River. We speculate that the pressure difference at the shallow unconfined aquifer system of the mountain-front alluvial fan induced by coseismic stresses must have caused channeling of groundwater to the rivers and the contemporaneous water level fluctuations in wells. Amplification of seismic waves at the thick, unconsolidated sedimentary strata of the Brahmaputra valley could have enhanced the extensive damage due to the 2021 Sonitpur earthquake. The present study has implications in estimating damage potential along Brahmaputra valley for future earthquakes.

CHEMICAL WEATHERING RATE OF A SMALL WESTERN GHAT RIVER, SOUTHWESTERN INDIA

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Quantification of chemical weathering of silicate rocks and associated atmospheric carbon dioxide consumption rates (CCR) is significant as it provides a better understanding of long-term climate change. Twenty four water samples were collected in monsoon, post-monsoon seasons of 2018, and pre-monsoon 2019 (9,8 and 7 samples respectively) from west-flowing Sharavati river catchment. This river originates in the Western Ghats and debouches into the Arabian Sea. The upstream of the terrain is mainly gneissic whereas the downstream comprises of gneiss, quartzite, schist, and greywacke. Samples were analyzed for major ions and physico-chemical parameters. Silicate Weathering Rate (SWR) for the watershed is estimated as 27 $t.km^{-2}.y^{-1}$. The samples from this study fall close to the silicate end member on the Ca/Mg vs Mg/Na plot. The presence of clay mineral kaolinite in the catchment indicates intense rainfall, hot and humid climate, and high silicate weathering rates. These factors and associated river discharge controls the major ion chemistry in the Sharavati river. The SWR obtained in the study area was compared with other small tropical watersheds in Africa, Brazil, and South America that has different lithologies. From the analysis, it can be concluded that all the small (< 4500 km^2) tropical watersheds showed control of rainfall irrespective of different lithologies and associated runoff on SWR. The calculated carbon dioxide consumption rate is 3.9 x 10^5 $mol.km^{-2}.y^{-1}$. Compared to other east-flowing rivers such as Krishna and Bhima, the SWR of Sharavati river is 2-3 times higher. CCR is 3.9 times higher than the global average on account of the peculiarity of the terrain. A further detailed study on a temporal scale will provide a clear picture of the river chemistry.

Drastic change in sediment provenance during the Permian-Triassic transition: An insight from Sr-Nd isotopic study of Guryul Ravine section, India

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The Late Permian mass extinction, the largest bio-crisis event in the Earth's history, was responsible for wiping out about 90% of marine and 75% of terrestrial species. The oceanic conditions of the Neo-Tethys during this event is well-preserved in the Guryul Ravine section (Kashmir) from the Himalaya. These sediments were deposited in depositional settings varying from shallow to deeper shelf regions, and have not gone through any major post-depositional alteration. Earlier studies have constrained the Permian-Triassic (P-T) boundary of the section through FAD of the *Hindeodus Parvus* in the E2 unit (bed 52) of the Khunamuh Formation. In this study, the Sr-Nd isotopic compositions in silicate fraction of these sedimentary rocks have been investigated to access change in sediment provenances across the boundary, if any. The $^{87}Sr/^{86}Sr$ ratios in the Late Permian samples from two Himalayan (Guryul Ravine and Spiti Valley) sections were found higher than that observed for the EarlyTriassic samples. Consistently, the average Nd isotopic (ε_{Nd}) compositions of the Guryul samples is found lower for the Late Permian (-13 ± 3; n = 10) than the Early Triassic (-9.6 ± 0.6; n = 15) deposits. This isotopic shiftaround the P-T boundary points to drastic change in sediment provenances to the Neo-Tethys. Lower $^{87}Sr/^{86}Sr$ and higher ε_{Nd} values for the Early Triassic samples indicate a relative increase insediment supply from the basaltic (than granitic) sourcesduring this period. Preliminary mass balance calculations involving Nd isotopes (assuming similar Nd concentrations for provenances and samples) indicate that the sediment flux increased by about two times during this period. Interestingly, this increased sediment supply from basaltic sources is synchronous to the extinction horizon identified earlier for this section. These observations from our study underscore importance of volcanic sources in driving the late Permian mass extinction event.

Extremely high-grade, lava-like rhyolitic ignimbrites at Osham Hill, Saurashtra, northwestern Deccan Traps: stratigraphy, structures, textures, and physical volcanology

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ABSTRACT

In many continental flood basalt (CFB) provinces of the world, widespread silicic lavas and ignimbrites overlie the mafic lavas. Our knowledge of this post-flood basalt silicic volcanism in the Deccan Traps CFB province of India remains limited. Here we describe the stratigraphy, structures, and textures of the rhyolites of Osham Hill in Saurashtra, in the northwestern Deccan Traps. Basaltic lavas forming the lower parts of the hill are overlain by the “Lower Rhyolite” (LR), which is tens of meters thick and shows intense rheomorphic deformation (flow banding and folding) at microscopic, outcrop, and tens of meters scales. The LR is overlain by a “Green Tuff and Pitchstone” (GTP) band 20-40 m thick, containing massive green tuff to strongly rheomorphic, commonly spherulitic pitchstone, both types showing sharp but irregular contacts. The GTP is overlain by the “Upper Rhyolite” (UR), with an ~100 m preserved thickness. This resembles the LR in many structural features, and also contains a thin (~1 m), laterally discontinuous basal layer of unbedded, nonwelded lapilli tuff. The LR and UR locally contain basal autobreccias which are unlike crumble breccias of rhyolitic lava flows. In thin section the LR and UR are microcrystalline and lava-like, though they contain many relict vitroclasts (glass shards and pumice fragments). The LR also shows rare millimeter-size basaltic lithic clasts. The GTP contains abundant vitroclasts. We interpret the LR and UR as extremely high-grade, intensely welded, lava-like ignimbrites, and the GTP as a low-grade ignimbrite with varying degrees of welding and rheomorphic deformation. The absence of sedimentary interbeds and soil horizons suggests that the whole Osham ignimbrite sequence was deposited subaerially and rapidly. The eruptive vent locations are unknown. However, a

rhyolite dyke intruding basalts at the southeastern end of Osham Hill is pyroclastic, showing a eutaxitic to microcrystalline interior and margins of welded and rheomorphic tuff-pitchstone. Basaltic lithic fragments found in the dyke margins suggest that it may be the feeder of the LR. The LR and UR show many close similarities to “Snake River-type” ignimbrites (large-volume, metaluminous, high-temperature, lithic- and crystal-poor, intensely welded, rheomorphic and lava-like ignimbrites). These render Osham Hill a newly recognised and important locality of such ignimbrites.

Morphometric analysis and weathering intensity in the Punnapuzha River Basin, central Kerala, India

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The geochemical records of clastic sediments represent an archive for studying their provenance as well as the tectonics and weatheringconditions in their source region (Singh and Rajamani, 2001a,b), whereas the drainage morphometric parameters are important indicator to understand the hydrological and morphological characteristics of any river basin. The present study is an attempt to investigate the regional topography and drainage dynamics of the Tuthapuzha river basin, a tributary of Chaliyar river (third largest river in Kerala), central Kerala, India, along with the geochemical behaviour of the bedload sediments. The morphometric analysis was carried out using SRTM data with the help of ArcGIS 10 software. The area of the basin is 450.65km^2 with its perimeter 117.77km and maximum length 47.95 km. Drainage patterns are dendritic to subdendritic with stream orders ranging from first to sixth order. Drainage density is 2.77 per km^2, while the bifurcation ratio is 4.15 for the river. The Punnapuzha River Basin is an elongated basin of small size. This basin might have originated during the Quaternary Period as a result of major tectonic activities in the region. The major oxide geochemistry of the sediments indicate that the dominant oxide is SiO_2 followed by Al_2O_3 and other oxides that suggests felsic-dominated source for the sediments. The chemical index of alteration (CIA), plagioclase index of alteration (PIA), chemical index of weathering (CIW), weathering index of Parker (WIP), Vogt S. residual index (V), Ruxton ratio (R), and silica-titania index (STI) reveal moderate weathering conditions and immature nature of the sediments in the basin. These suggest that the sediments experienced a moderate amount of weathering in the river catchment under subhumid climatic conditions.

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Significance and role of controlling factors in the chemical weathering of Amphibolite: an overview

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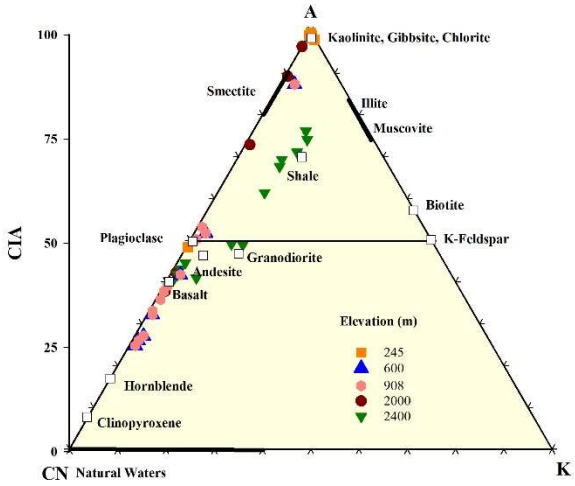
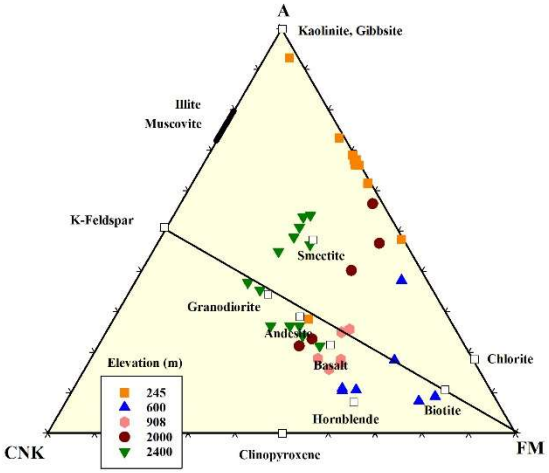
Abstract

Chemical weathering is a complex process, and it is not easy to generalize the factors controlling the geochemical behavior of elements during chemical weathering. However, the mobility and redistribution of elements in weathering profile could be location-specific. In the current review, five weathering profiles developed on amphibolite parent rock at different altitudes were chosen to compare the geochemical characterization of weathering products of amphibolite. A statistical test (*t*-test) carried out of bedrock suggests no statistically significant differences in the chemical composition of bedrocks ($p > 0.05$). The chemical index of alteration (CIA) and other indices are used to determine the degree of weathered rock alternation, indicating incipient to advanced weathering intensities. Relative mobility calculation suggests that the variation in the enrichment and depletion of certain major oxides indicates that the mobility of elements within each profile seems to have distinct controls. Comparing the chemical weathering characteristics of these profiles and seismic activities at their locations suggests that tectonic stability can affect the weathering process development via enhancing drainability of rocks, which leads to removal of weathering products and decreasing weathering advancement.



A: Al_2O_3, CN: $CaO + Na_2O$, K: K_2O



A: Al_2O_3, CNK: $CaO + Na_2O + K_2O$, FM: $Fe_2O_3 + MgO$

Evolution of Kamthai carbonatites, Rajasthan: Evidence from geochemistry

Milan Kumar Mahala and Jyotiranjan S. Ray

Abstract

A geochemical and isotopic (Sr-Nd-C-O) study of rock samples from the Kamthai carbonatite-alkaline complex, Rajasthan was carried out to understand the mode of origin and evolution of carbonatites, their genetic link, if any, with the associated alkaline silicate rocks, and assess the hypothesis that the magmatic activites in the complex were linked to the Late Cretacous Deccan-Reunion mantle plume. The carbonatites in the complex comprise mostly calciocarbonatites with minor ferrocarbonatites, and the associated alkaline silicate rocks are primarily nephelinites, nepheline syenites, and phonolites. The $\delta^{13}C$ and $\delta^{18}O$ of unaltered carbonates from the carbonatites and alkaline silicate rocks show primary or magmatic compositions ($\delta^{13}C_{V\text{-}PDB}$ = -4‰ to -8‰, $\delta^{18}O_{V\text{-}SMOW}$ = 6‰ to 10‰), with a significant number of samples showing mantle compositions. Altered carbonates from both rock types show larger variations in both isotopic compositions, with some showing very high $\delta^{18}O$ (≥ 15 ‰). The correlated variations of $\delta^{13}C$ and $\delta^{18}O$ observed in primary carbonatites are likely the result of fractional crystallization of a parental carbonate magma rich in CO_2+H_2O fluids. The rare earth element (REE) contents of these carbonatites, particularly the late-stage intrusives, are very high, often reaching percentage levels. They all show light REE enriched patterns in chondrite normalized plots. Variations of trace element ratios in alkaline silicate rocks attest to the evolution of the alkaline silicate magma for the complex through fractional crystallization. The age-corrected (or initial) $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios of the carbonatites and most of the alkaline silicate rocks overlap suggesting derivation from the same mantle domain; however, some of the evolved members of the alkaline series show signs of crustal contamination. The carbonatites and alkaline silicate rocks have lower εNd_t and higher initial $^{87}Sr/^{86}Sr$ than the present-day values of Reunion plume basalts and the age-corrected values of the Ambenali formation of Deccan flood basalts. However, similar emplacement ages, OIB like trace element signatures of the less differentiated alkaline rocks, and near initial bulk silicate earth (BSE) $^{87}Sr/^{86}Sr$ values suggest they might have a genetic link with the plume.

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Lithospheric Velocity Structure beneath The Chhotanagpur Plateau, India Using Waveform Modeling Of Shear-Coupled PL Wave

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Abstract

The presented research utilizes the constraints imposed by Shear-coupled PL (SPL) wave and its associated phases to decipher seismic velocity structures of the crust and upper mantle beneath the Chhotanagpur Plateau, India. For this purpose, the best quality teleseismic earthquakes' waveform from broadband data of magnitude between 5.5 to 8.0, focal depth ≥ 300 km, and epicentral distances between 30^0 and 70^0 are extracted from seismic stations located at Dhanbad (DHN), Bokaro (BOKR), Petarwar (PTWR), Khunti (KNTI) and Sahibganj (SBG). A modified form of reflectivity method is consulted to generate synthetic seismograms for various angular frequencies where the calculation of response matrices is distributed over various nodes of the High-Performance Computing (HPC). The forward calculation is benefitted from twenty two nodes of HPC to significantly reduce the computation time. The crustal thickness of the study area varies between ~40.5 km and ~45.6 km. The thickest and thinnest crust are reported on the NE and SW parts of the study area underneath seismic stations SBG and KNTI, respectively. The observed thick crust for SBG may be due to the subsidence of the Indian lithosphere beneath the Himalayan footprint. A low-velocity zone in upper-crust observed in seismic station SBG due to the sediment deposition of Ganga-Koshi formation. The statistical tools such as the Posterior Probability Density function (PPD) and Parameter Correlation matrices (PCM) are used to find the uncertainties around best-fitting models and assess the trade-off between model parameters in the modeling scheme.

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Impact of extreme rainfall events on chemical weathering in a tropical river basin (Mahanadi river, India)

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Concentration-discharge relationship in a watershed provides quantitative assessment of seasonality in solute fluxes, weathering reactions and short-term weathering-climate linkage. In this contribution, time-series analysis of major ions chemistry of a Mahanadi distributary (Paika river, India) was carried out for a duration of 15 months (Aug., 2019-Oct., 2020) at weekly interval. The total dissolved solid of this river varies between 90 and 305 mg/L, with an average value of 183 mg/L (n = 65). Average silica content of this stream (264 μM) is about two times higher than that reported as global average for rivers (127 μM; Tripathy and Das, 2014). Water chemistry of this monsoon-fed river shows significant seasonal variation. Most of the elements show relatively lower concentrations during monsoon (by ~1.5 to 3 times) compared to that during the non-monsoon seasons. This decline in concentrations cannot be accounted to dilution effect alone, as these changes are disproportionally lower than the discharge changes observed for the Mahanadi. This observation points to intense chemical weathering during the monsoon and hence, confirms a strong weathering-climate interaction in this tropical basin. In addition to this broad seasonal trend, a systematic decline in concentrations was also noticed during a specific (19 April- 24 May) period in the pre-monsoon season. This sudden change in water chemistry is synchronous to an extreme rainfall event occurred during this period, which is related to a super-cyclone developed over the Bay of Bengal. This change in elemental concentrations and their ratios indicates significant impact of super-cyclones on chemical weathering pattern of river basins, which may influence the annual fluxes of chemical constituents via rivers to the oceans.

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Analysis of Seismic Attenuation Characteristics for Eastern Chotanagpur Plateau, India

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Abstract

The Chotanagpur plateau is located at the northern periphery of the Singhbhum craton which manifests the north-eastern projection of Indian peninsula. Due to the presence of complex regional faults and the seismogenesis from the Himalayan collision zone in the north, the study region has suffered some moderate magnitude earthquakes, namely Hazaribagh (1868, M 5.0), Manbhum (1868, M 5.7), Bihar (1958), Ranchi (1963, M 5.0), Bankura (1969 M 5.7), Deogarh (2015, M 4.0), Sahibganj (2020, M 4.3), Deoghar (2020, M 4.1) and Jamshedpur (2020, M 3.9) along with some damaging historical major earthquakes viz. Bihar-Nepal border (1833, M 7.6), North of Bihar-Nepal Border (1934, M 8.1), Bihar (1988, M 6.8) and the most recent Gorkha Nepal earthquake (2015, M 7.8). In order to get insights into the seismicity, it is indispensable to study the attenuation characteristics of the region through estimation of Kappa (κ) and Coda-Q (Q_c) models for further stochastic simulation of ground motion. We use 139 seismic event records from sparsely located six broadband stations deployed in eastern part of Chotanagpur Plateau at Indian Institute of Technology, Dhanbad (IIT(ISM)), Sahibganj (SBG), Khunti (KNT), Bokaro (BOKR), Nirsa (NRS) and Peterwar (PTWR). Our results reveal that the average 'κ' value lies around 0.0364 for the region, which is dependent on the epicentral distance and independent of event's magnitude. The Q_c values are calculated for three-time windows of coda arrivals viz. 40 sec, 50 sec and 60 sec and are strongly dependent on frequencies. The calculated Q_c values are fitted using power law, $Q_C = 281.09 f_c^{0.80}$, and is found to increase with increasing coda window. The extinction distance (L_E) indicates that the upper mantle is homogeneous and attenuation with in the depth range 86 km to 119 km is comparatively less. Peak Normalized amplitude estimated for all six stations show decay with increase in distance. The lower Q_c values in the Bokaro region indicate presence of heat zones. The Q_c and 'n' values on comparison with Q_c model developed for other regions show that they lie between those of active and stable region implying moderate seismicity in the Eastern Chotanagpur Plateau region.

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Figures

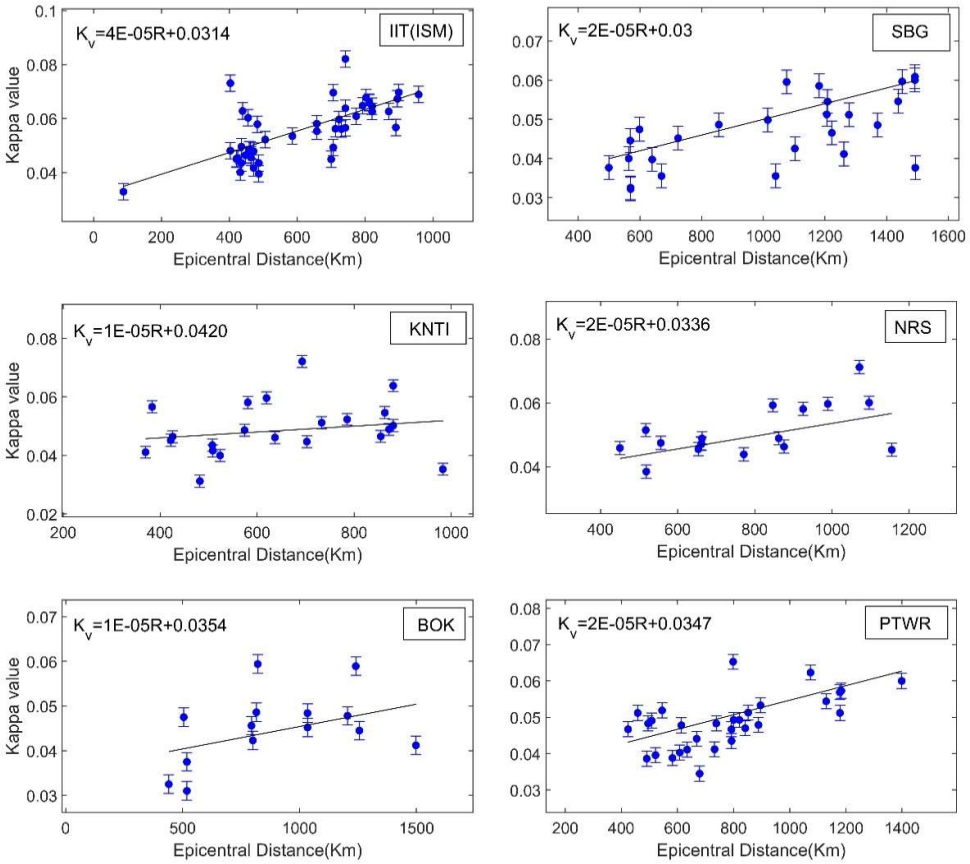

Figure 1. The figure shows the Kappa Model developed for all six stations (IIT(ISM), SBG, KNTI, NRS, BOK and PTWR). The κ values obtained for vertical component of each event is plotted with epicentral distance and fitted by a straight line. Each plot also shows the model equation and name of the station.

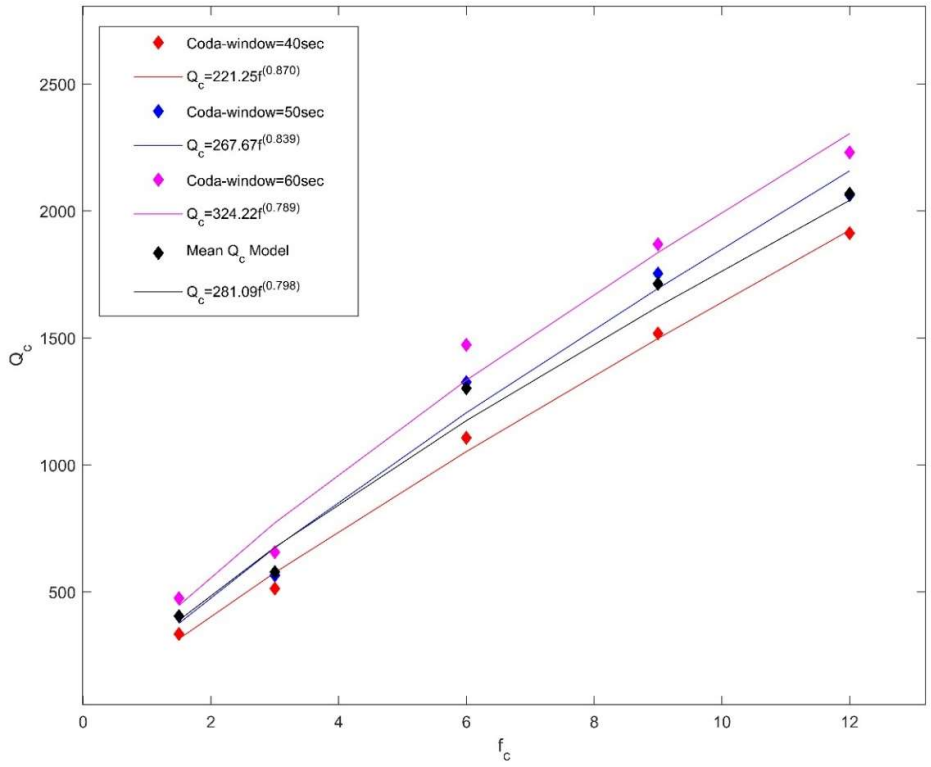

Figure 2. This figure shows plot for Coda-Q model at three Coda windows (40, 50 and 60 s) obtained from all six stations. The figure also shows plot for average Q_c model. The Q_c values (plotted with red, blue and magenta diamond shaped markers) are plotted against f_c and a power law model ($Q_C = Q_o f^n$) is fitted for each Coda window. The equation shows the power law model obtained after fitting the Q_c values.

Silicate versus carbonate rock weathering in Peninsular India: a study from the Kali watershed.

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Abstract: Riverine chemistry of Kali watershed draining mixed silicate/carbonate lithologies was investigated to differentiate the impacts of silicate and carbonate rock weathering on river chemistry. Analysis of water samples for various Physico-chemical parameters and major ions were carried out for monsoon (July 2018), post-monsoon (December 2018) and pre-monsoon (May 2019) seasons. Stream water chemistry exhibits discrepancy in upstream, midstream, and downstream regions reflecting the slight variations in bedrock geology (weathering of silicate and carbonates rocks) and contributions from marine aerosols or other salts and anthropogenic sources. The catchment experiences intense chemical weathering on account of heavy rainfall, intense runoff during the monsoons. The estimated silicate and carbonate weathering rate is 41.3 t. km^{-2}. y^{-1} & 6.9 t. km^{-2}. y^{-1} in the river catchment. This could be attributed to intense rainfall-runoff and the nature of lithology, which mainly comprises greywackes, tonalitic gneiss and patches of limestone.

Comparison of Seismic Declustering Methods for Kishanganj (India)

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This study appraises the seismicity of Kishanganj, a bordering district of Bihar, India and its adjoining region within a radius of 500 km by using several different Declustering methods. The methods are proposed by Gardner and Knopoff (1974), Zhuang et al. (2002) or stochastic declustering algorithm and Reasenberg (1985). From the results, it is clear that each algorithm has different influence on raw catalog, which may, in turn, provoke influences on seismic hazard analysis. The Gardner and Knopoff (1974) algorithm, which is a window based method, yields only 19% of clustered events and removes 81% of total events, thus fails to consider all the background events. This algorithm also spots the foreshocks and aftershocks with a greater shaking intensity than their analogous parent events. This may be due to the application of window method in Gardner and Knopoff (1974) algorithm. The Reasenberg (1974) algorithm, which is a clustering based method, removes 13.7% of the total events. This algorithm removes relatively less amount of foreshocks and aftershocks. The Zhuang et al. (2002) proposed an algorithm, based on Epidemic Type Aftershock Sequence (ETAS) Model (Ogata, 1988 and Ogata, 1998) also known as stochastic declustering, which removes 33% of offspring events. This algorithm amalgamates the parametric maximum likelihood for clustering structures by employing space-time ETAS model and the non-parametric estimate of parent seismicity also known by variable weighted kernel estimate. The clustering and window methods are easier to execute than stochastic declustering. From this study, it is clear that clustering method is suitable to our study region for declustering and seismic hazard analysis.

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Comparison of the LST, NDVI, and NDBI between the old Ahmedabad city and the new Ahmedabad city using the LANDSAT-8 satellite

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ABSTRACT

In this study, a comparison between the Old Ahmedabad city (eastern side of the river) and the New Ahmedabad city (western side of the river) is made in terms of LST, NDVI, and NDBI. These are obtained by using the data derived from the LANDSAT-8 Operational land imager and Thermal infrared sensor (OLI and TIRS) in the Google Earth Engine (GEE). In this study mean values of LST, NDVI, and NDBI for different seasons of the year 2020 are considered for both parts of the city. The mean value of LST, NDVI, and NDBI during the entire 2020 year for the new city was found out to be around 29.9° C, 0.3164 & -0.0410 respectively and for the old city, the values were around 30.5° C, 0.2285, and -0.0020 respectively. This represents that for the year 2020 the mean LST of the old city was about 0.5-0.6 ° C more than the new city which accounts for about 1.8 % more LST value than the new city. The values of NDVI & NDBI of the old city were 27.3 % less and 95.2 % more than the new city respectively. The maximum values of LST, NDVI, and NDBI for both the parts of the city were in the pre-monsoon, monsoon, and winter respectively. It was also observed for both parts of the Ahmedabad city that the LST and NDVI are maximum correlated (negatively) during the monsoon season and LST and NDBI are maximum correlated (positively) during the post-monsoon season. Also, these correlations were found out to be better for the old Ahmedabad city. From this study, it can be known that the old Ahmedabad city is having higher LST values due to its highly dense built-up areas and fewer vegetation areas and this trend is observed for all the seasons of the year.