Catastrophism and uniformitarianism in Decision Making of Meghalayan Age in East India.

Abstract

Penultimate Epoch is the Holocene, had three-way broad subdivisions (late 11.7KYBP (Year before Present), middle 8.325KYBP, and early 4.6KYBP) based on numerous imprints of geomorphologic, meteorological, ice-core, speleothem, and vegetation proxies in nature. Micro-scale ratification of the Holocene epoch, was Greenlandian (11.7KYBP-8.2KYBP), Northgrippian (8.2 to 4.2KYBP), and Meghalayan stage from (4.2KYBP to 50YBP), considering year 2000AD as threshold (b2k) based on DYE-3, GRIP, NGRIP1, NGRIP2 and GICC05, the Greenland Ice Core Chronology 2005 records. The Meghalayan age started with 200years mega drought that shattered primeval agriculture based civilization globally. The stalagmite from various rocks, archeological findings, pollens, δO18 isotopic studies and anomalies in Indian summer Monsoon imprints emphasize collapse of well-set Northgrippian Human civilizations in Mesopotamia, Indus and Ganga river plain (Indian subcontinent), the Akkadian Empire (NE Syria). The stratigraphic records offer evidences climate changes, RSLR, geomorphologic, vegetative cover, Hydrologic processes. The stalagmite proxies, shift of ISM, erratic ITCZ annual drive, left proxies in Stalagmites, in the Mawmluh cave could end to the Holocene epoch classification. The Meghalayan age left exhibits of the upper Holocene that sprinted with severe prolonged droughts due to unstable erratic climate, multiple apocalyptic hazards, and extreme events due to sun-earth geometry, like shifts in Indian summer monsoon, ITCZ, westerly disturbances, and ENSO activities along eastern part of Himalayas. The ratification and retrofitting of the geological time scale during Holocene well organized with respect to biostratigraphy in Indian subcontinent.

Keywords: Climate Changes, Holocene, ISM, Meghalayan, stalagmites, Eastern India,

Introduction:

The earth is 4.54bi years in age and gone through various transformations synchronous with geo-chronometric age as established from radiometric dating of fragments from the Canyon Diablo iron meteorite. In 2018, newest accepted geologic time scale as per the International

Chronostratigraphic Chart International Union of Geological Sciences (IUGS) the Holocene epoch has been subdivided as Greenlandian (11.7KYBP before the year 2000 (b2k)), Northgrippian (8.3 KYBP b2k), Meghalayan (4.2KYBP before b2k), and later succeeded by the Anthropocene epoch, yet not included in Chronostratigraphic Chart 2018. In GSSP run, the 1st marker is bio-stratigraphy whereas the secondary marker considered as the physico-chemical for future GSSP, (Lucas 2018[1], Davydov 2020[2], Head 2021[3]). The stratigraphic timescale used for the Greenland ice cores NGRIP (I), at 75.10°N; 42.32°W) and NGRIP II (75.10°N; 42.32°W), GRIP, and DYE-3 until 2005. Currently the Centre for Ice and Climate adopted a new timescale in 2005 as the Greenland Ice Core Chronology (GICC05). The NGRIP, and GRIP ice cores, cover the period 7.9–14.8 KYBP (the Bølling, Allerød, the Younger Dryas, and the early Holocene), (Rasmusser et al., 2007[4], Walker et al., 2018[5]). The Anthropocene has coined with substantial consumption carbon energy that have thwarted the natural earth system, (Mishra S. P. 2017[6], Martin et al., 2021[7], Bojie et al., 2022[8]).

Catastrophism gives a picture of the changes in the geo-hydro-bio sphere on the earth crust with time. The uniformitarianism depicts the continuous and regular changes that occur to the earth crust. Present study is the unveiling of the catastrophic sequences in an uniform manner to explain the dark period from 4200YBP to 50YBP under base period 2000.

Table1: The revised classification of the Holocene by GSSP (ICS)

EON/ERA /Period	Epoch	Age	Years	As per markers	Physiognomies
Phanero-zoic /Cenozoic /Quarter-nary	Anthop -ocene	Not named	1950-till date yet to be stamped	Demography and human overrule Geo-bio-hydro-environment	Maximum energy use, Human stress on earth; drying of Aral Sea
	Holocene (As per DYE-3, NGRIP, or GICC-5	Meghalayan; Upper/ Late Holocene	4.2kyr b2k; less shown GICC05 time scale;	Bio-stratigraphy/ physicochemical as 2ndsry marker with Human impact; (δ18O);	Cave Mawmluh; The Lower Eocene Lakadong dolomite (Calcium rocks) & Therria Sandstone
		Northgrippian; Middle /Mid Holocene	8.2KYBP b2k; NGRIP 1 ice core.	Bio-stratigraphy as 1st hand marker climatic cooling tailed by rising temp^{re}. during the Early Holocene	Central Greenland (75.10°N; 2.32°W) It is the ice core at a depth of 1228.67m, near the 8.2 ka event

		Greenlandian; Lower/ early Holocene;	11.7KYBP 0b2k; & NGRIP 2	Change of the evaporation at rain/snow source after Greenland Stadial1/Younger Dryas, together with changes in dust load,& CC	The central Green-land ice sheet; subseries /sub-epoch is located at 1492.45 m in the NGRIP2 ice core

The Meghalayan started 4.2KYBP, shaped by continuous 200years mega-drough/ very high flood phenomenon that shattered well-developed civilization in Asia such as Mesopotamia(for prolonged salinization in Syria), Yangtze Valley, Nubia (reduced river flow), Indus valley (Mahenzodaro and Harrapan), Ganges flood plains (Mahajanapadas), Egypt, Greece (Anatolia), Israel, Palestine, and Turkey, cultures across the globe where tropical monsoon went weak. The changes were due to shift of monsoon pattern, ITCZ, Huge Azores High and the western disturbance after a good SW monsoon period in mid-Holocene (Northgrippian) period, (Kidder et al., 2012[9], Kathayat et al., 2017[10], Jacobson et al., 2021[11]). Later during mid Meghalayan period many Vedic civilizations on Ganga River Valley (Guje Kingdom, Sahiya), due to shift of ISM and ICTZ.

Reasons for study:

The world has encountered a series of climatic extreme events and various types of apocalyptic disasters in last two decades from 21st Century. The cataclysm of all types of waves of disasters like biological (Pandemics), Geophysical (Tsunamis); Earthquake (Haiti); Volcanic activities (Hunga Tonga) and many others passed over India. The conception of those are not instantaneous but a continuous change in sun-earth geometry. The geo, bio and hydrological changes are the results of geospatial complexities of climate changes inherited from paleo climatic proxies. From ice core explorations from Greenland the first two ages of Holocene epoch prefixed from ice core studies such as Greenlandian and Northgrippian. The penultimate compartment and its geological establishment was only possible after exploration of the stalagmites from the Calcareous Rock fabric Mawmluh cave. Present study is an attempt to study the available paleo-climatic proxies to phase the Meghalayan age from 4.2KYBP to 70KYBP, and link with the climatic vicissitudes that has occurred during the Anthropocene epoch.

Methodology

Meghalayan word hailed from the demarcated rock mosaic analyzed by Mike Walker (ICS, 2018) located in the stalagmite in one of the longest and deepest Cave Mawmluh entrance (25°15'44"N; 91°42'54"E) at 1290m high stalagmites proxies in the Meghalaya state, east India. The stalagmite established through various oxygen isotopes of differential numbers of neutrons that recognized dry paleo-climate and weakened the paleo- monsoon (between 4300 to 4100 Years before present, YBP) Vyawahare 2018[12]. The rock slice and the mosaics formed links to major geological activities like splitting of continents, swings in climate, and can be associated with appearance of various types of the biome with geological time scale, (Amos J 2018[13]). Because layers of stalagmites/stalactites are shaped due to deposit of calcium opulent water infiltrating into the cave surface. The tephrochronology study of layers signify cycles of deposit of calcareous materials (volcanic ashes) dated by isotopic methods. The Meghalayan age accepted officially by International commission of stratigraphy (ICS) on July 13, 2018 (Walker M., 2012[14]).

The Archives which signifies about an geographic stages are fluvial, marine and windblown sediments, lake and peat from lacustrine areas, glacial moraines and proglacial deposits, ice cores, corals, speleothems, tree rings stalagmite and tufa's. The Proxies that also helps in ascertaining the geomorphic changes with geological time scale are sediment size/distribution, mineralogy changes, Pollens, Magnetic properties of minerals. The fossil imprints, isotopic composition of organic matter, Oxygen, Nitrogen, carbon and hydrogen, carbon vs Nitrogen, Formation of gypsum under extreme climate etc. add to it., Harris et al 2008[15], Singhvi et al., 2008[16], Laskar et al, 2021[17])

Various methods to ascertain geospatial age

i. A= Age of a phenomenon = $\frac{A_p - A_f}{A_u}$ eqn 1

Where A = age to be determined; A_p = present status of activity; A_f = time taken for reaching final status of activity and; A_u = unit rate of activity (Singhvi et al., 2008)

ii. Geo-chronometry method to find the age by dating method where the depth of the stratigraphic layer, more is the relative age under sub-jurisdiction of degenerative process and the amount of organic residue left.

iii. Carbon dating method: Carbon has three isotopes i.e. carbon-12 ($^{12}C_6$), carbon-13 ($^{13}C_6$), and carbon-14 ($^{14}C_6$). Carbon-12 and carbon 13 are stable whereas carbon-14 is unstable and undergo radioactive decay and transforms stable nitrogen ($^{14}N_7$) which take a long period depending upon half-life period. Radiocarbon dating used to measure ages of things that were geologically recently formed (initial av. half-life 5730 for each half-life and used for age range of application of 70000years). The carbon dating used against organic material are bones, wood, charcoal, shells (Peppe et al., 2013[18]).

The radiocarbon dating equation of $^{14}C_6$ to $^{14}N_7$ is:

$$^{14}C_6 \Longrightarrow {}^{14}N_7 + e^- + \mu_e \qquad \text{eqn-2}$$

$$N_t = N_0 e^{-kt} \qquad \text{eqn 3}$$

And

$$k = \frac{\ln 2}{t_{0.5}} \qquad \text{eqn 4}$$

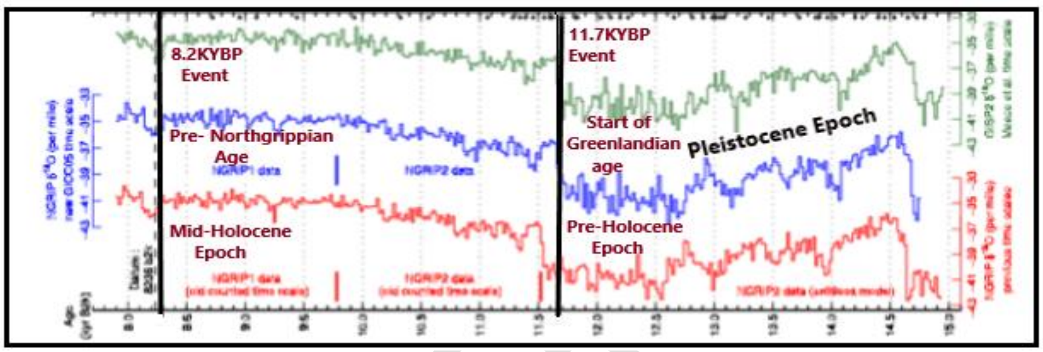
Where N_0 = Number of atoms of the isotope in the original sample (when time t = 0), Nt = Number of residue atoms on elapse of time (t). k = the rate constant for the radioactive decay

The other physical dating methods used are K-Ar dating for potassium/glass minerals, Luminescence (10 to 10^6 YBP) for Quartz, feldspars, carbonates etc., Fission tracking (1,000 to billion YBP) and many others. The chemical dating methods in geological correlated with existence of similar fossils called "Biostratigraphy" or "Tephrochronology" where the Sediment/ashes strata like Foraminifer, Ammonite occur in identical age. The Annual Layer Counting Methods, i.e. dendrochronology or lake sediments or speleothems analyzed to find the age of the proxies.

Present study includes study of all the available methods and proxies to construct the Holocene epoch that induced its shift to the Anthropocene Epoch perturbed the geo-bio-hydro sphere.

Ice core exploration Green land:

Haas et al., 1998[19] identified six compartments in Holocene epoch 9.6 to 9.2KYBP, 8.6 to 8.15, 7.55 to 6.9; 6.6 to 6.2; 5.35 to 4.9; 4.6 to 4.4; 3.5 to 3.2 and 2.6 to 2.35KYBP as radiocarbon years considering the climates of sites at Alps and Swiss Plateau. The 21st century Greenland ice core chronology depicted from the DYE-3, GRIP, and NGRIP (I, and II) ice cores, identified as the Greenland Ice Core Chronology 2005 (GICC05). The ice core tell less about the late ages of the Holocene epoch. The Global Boundary Stratotype Section and Point (GSSP), as per the NGRIP2 Greenland ice core at a depth of 1492.45 m. dated back to 11.7KYBP b2k (before 2000 CE) event (Greenlandian age). The NGRIP1 ice core, at a depth of 1228.67m signifies 8.2KYBP b2k event. The late Holocene setting at the 4.2KBYP b2k event (Meghalayan age) could not be explained by the ice core or by GICC-5 chronology. The speleothem from (Stalagmite KM-24) in Mawmluh Cave, Meghalaya, could able to help the geologist for the 4.2KYBP event ((Rasmussen et. al., [20] and Walker 2018[5])



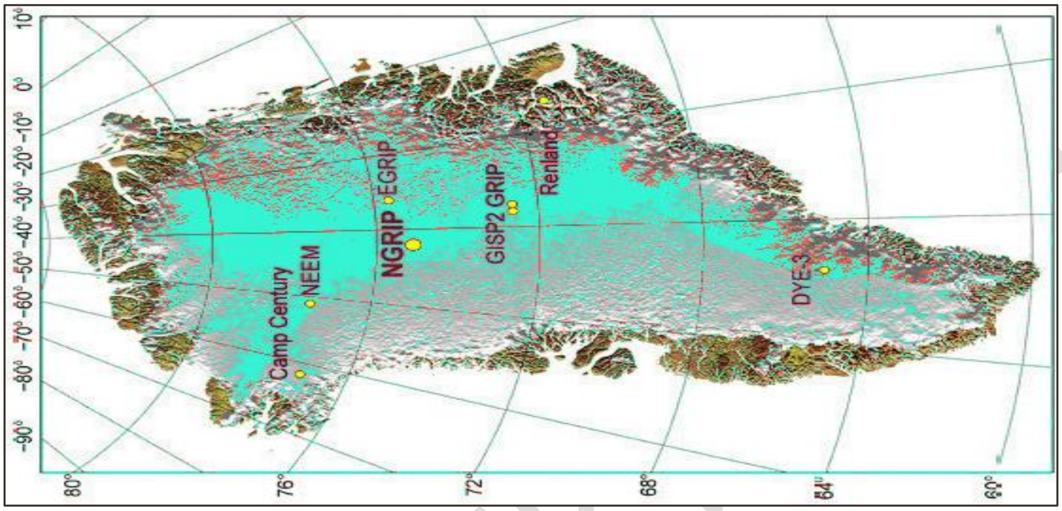


Fig 1: Greenland Ice core records (DYE-3, GRIP, NGRIP (I, and II) and GICC-5; less presenting late Holocene (Meghalayan age) (Source modified Rasmussen et. al., 2006[20] and Walker 2012[14])

Speleothem Stalactites and Stalagmites Eastern India

Speleothem, stalactites and stalagmites in Caves in India (the $CaCO_3$- H_2O) paleo-thermometer) provide important proxies of Holocene paleo-climate and paleo-monsoon, as not subjected to erosion, diagenesis. They are calcite and aragonite materialization in speleothems of different hills and their cave systems and terrestrial deposits. Meghalaya. The geological formation has 200km long x 30km wide lime stone band plunged into range of hills of West Garo, West Khasi Hills, eastern parts of Khasi and Jaintia Hills **(Fig -1).** The Meghalayan Adventures Association (MAA) has explored cave passage of length 320km and about a milieu of entrances to these caves at a height of 1000m to 1100m and some uncharted. The bio-speleology search has explored some caves (krems in local name) like Um-Lawan, Mawkhyrdop, and Mawmluh, Wah Ser, Krang Maw, Siju, Pyrda, Umthloo, Kotsali, and Wah Tylliang etc in Meghalaya. Mawmluh is 8th stretch of cave of span 7194m with about ≈ 4000m is undefended for caving by Meghalayan adventure association (MAA). The stalagmite in the Himalayas (Chulerasim), Bhimbetka caves (Bhopal), Mawsmai (Shillong), Kailash, & Kotumsar caves (Basstar, Chhattisgarh), Belum caves (AP at 3229m), Gupteswar and Khandagiri caves (Odisha), Mahakal caves WB, Dungewari caves (Bihar), and Borra Caves etc. are the exhibits and proxies that depicts about Meghalayan age which are yet to be studied.

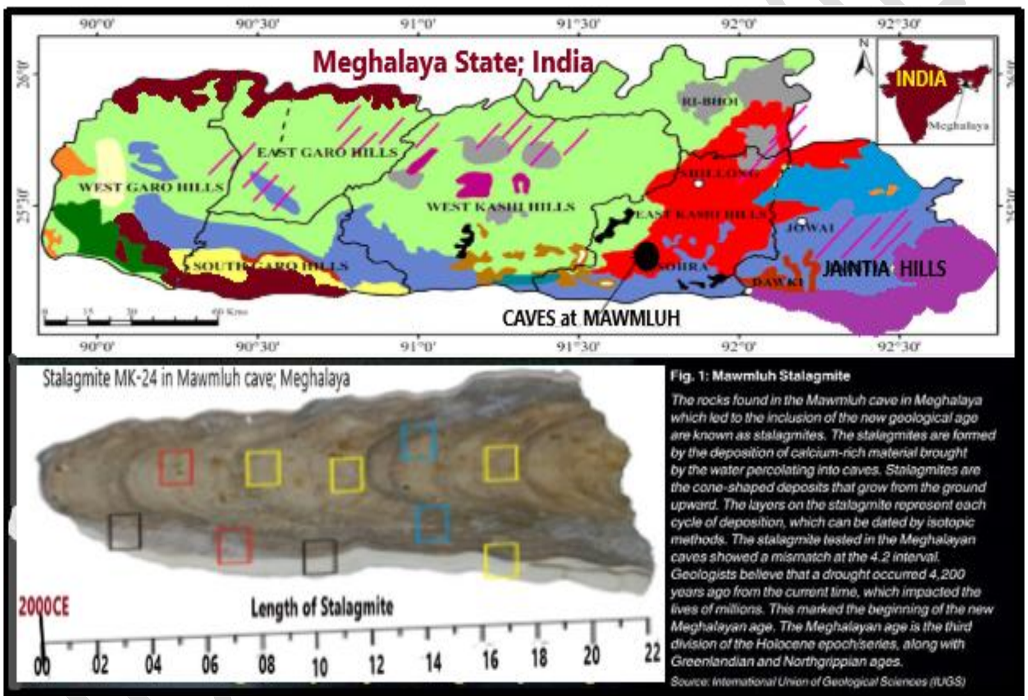


Fig 2: The Index map and multy-proxy of the Meghalayan age stalagmite, East Khasi Hills, Mawmluh cave, (KM-24), (source modified: Kalpana et al., 2021[21], Dildi et al 2021[22])

The petrogenic study of calcareous stalagmite, at the Mawmluh cave entry, East Khasi Hills on river Lum Lawbah, in 2012 revealed a ratification of geological age of the late Holocene epoch as the Meghalayan stage from 4.2KYBP b2k. Walker and Rasmussen are the geologist analyzed the rock fabric and could solve the after myth of the 4.2kybp events bio-strati graphically. The before present (BP) refers to is the year 1950 i.e. start of Anthropocene whereas b2k of the ice core considered before the year 2000. Other targeted stalagmites explored are Mawkhydrop, Mawsmal, Rupnath, Mondilcole etc., Harrish et al., 2008[15].

Archeological Findings India

Many archeological findings against fall of civilizations, such as Mesopotamia, Akkadian Empire, and BET Dwarka submerged Island; Durgadevi (WB) Sindh civilizations (Harrapa and Mohenjo-Daro) are contemporary to early Meghalayan stage. The archeological excavations, rock records, speleothems, radiocarbon studies, dendrochronology about the Holocene rainfall incidences and climatic variability affecting agriculture, lake/lagoon morphology, (Weiss et al., 1993[23], Cullen et al., 2000[24], Kotlia et al., 2015[25], Komg et al., 2017[26], Weiss, H., 2017[27], Quamar et al. 2021[28]).

Review of literature:

The human settlement with agriculture based life probably started around early Holocene time. The history of habitation in India as hunter-gatherers dates back to 30KYBP as per haplo groups DNA tests. That proved Indians are West Eurasian origin, particularly in Hindu upper cast. The existence of homosapiens found in various excavations and stalagmites even up to 65KYBP (Singh et al., 1999[29], Bamsad et al., 2001[30], Banerji et al., 2017[31], Clarkson et al., 2020[32], Callaway 2021[33]). The climate change (CC), in short or spatial scale in ISM linked with agricultural yield, socio-political economy, prevalence of biological disasters, and geo-bio–hydro sphere in Indian subcontinent. The climate is the cooling engine of the earth's planetary system, Berkel. H 2012, Chiotis 2018[34].

The trade winds, El Niño and the Southern Oscillation (ENSO), irregular oscillation of sea surface temperatures, the asymmetrical oscillation of SST (sea surface temperatures) called positive Indian Ocean dipole (PIOD) etc. are the associated meteorological phenomenon associated with the climate change of India. (Wang et al., 2005[35], Borzenkova et al., 2015[36], Mishra S. P. et al 2020[37]). Late Holocene massive drought/famine is rock record neither a myth nor a Hyper object proved by rock records anointed as 4.2KYBP-old event or Meghalayan emergence by the International Commission on Stratigraphy (ICS) in 2018, after Walkar, 2012[14]

The multi-proxy data, such as pollen records, Radio carbon dating, paleo-temperature, lake sedimentation, sediment transfer, ecological collections reveals about earth science changes. The Meghalayan stage of late Holocene climate has been compartmentalized with median spacing of 400yeas with control point being 3000YBP, both in Mid latitude and equatorial regions, Sun et al., 2013[38], Jenny et al., 2019[39], Kaufman et al., 2020[40], Hao et al., 2021[41].

Paleontology proxies:

The Meghalayan cooling events in the Last Ice Age (LIA) has paleo-climatic and archaeologic evidences from India. They indicate that the setting of the nature and societal changes have substantially influenced the abrupt climate change around 2.8ka BP (Park et al., 2019[42]).

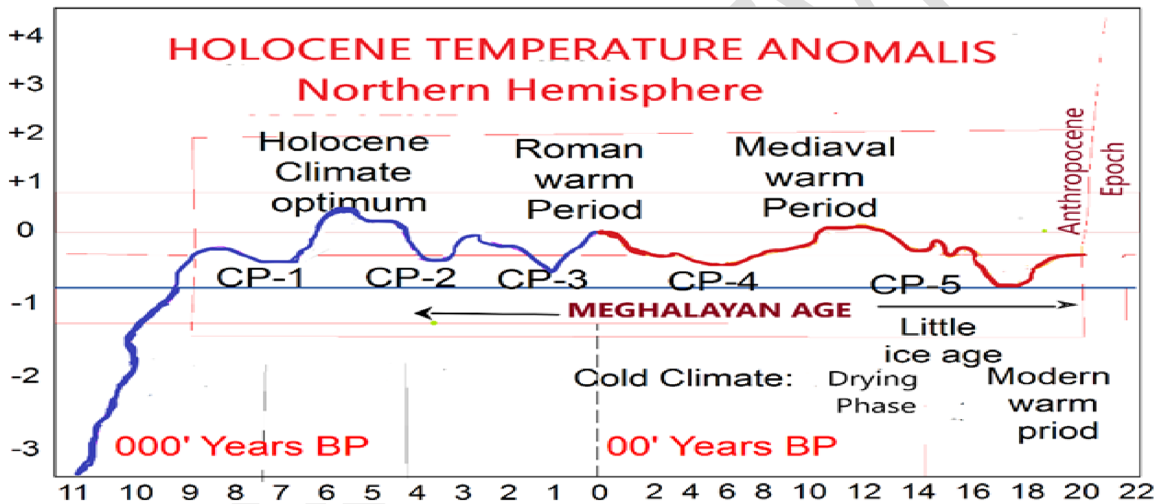


Fig 3: Holocene temperature anomalies during Meghalayan era

Pollen records (arboreal pollen percentage data) reveals the drying spells during the latter part of the Holocene epoch. The Late Holocene was compartmentalized four-time spans 4.2ka-3.7ka, 3.2 ka-2.8ka, 2.8ka to 2.4ka, and 2.4ka BP to present. The cooling episode was due to solar-insolation shift in atmospheric circulation. The mega droughts between 4.4ka to 4.0KYBP led to the collapse of ancient civilizations in East Asia. (Fairbridge et al., 1976[43], Park et al., 2018[44], Mishra et al, 2021[45]), sparse pollen proxy data is available with some legendary and epic evidences of the late Holocene period in eastern India

The Kemp Mawmluh, of Meghalayan age is 7.15km long and rich in mineral deposits and adorned with numerous formations of stalactites and stalagmites, Chambers, rivers, moon milk, fishing pond, crawling part, vertical holes, etc. The stalagmites and the rock fabrics in the Mawmluh caves represents prominently the proxies of growths in stalagmites occurred during various geological time scale and prominently the Meghalayan age (4.2K to 0.07K YBP), **(Fig 3)** Walkar, 2012[14]

Fig4: Photographs inside caves of Mawmluh; (source: https://www.tripadvisor.in /Attraction)

Multi-proxy flood records:

Evidences of sedimentary sequences in rhythmic cycles recorded in the various rivers in like the Ganges, the Brahmaputra and the Mahanadi system in Meghalayan age. The Sagar island (21°37’21’’to 21°52’28’’N lat. and 88°2’17’’to 88°10’25’’E long.),(Gopinath et al., 2005[46]) Mahisani island, mud point island at the Hugli estuary of the Ganga system. Similarly, the Mahanadi delta system has shown retrograding shoreline during Meghalayan age with huge sediment influx and flood flow with deltaic progradation and sea level adjustment. Major changes in delta building processes occurred during late Holocene up to 800YBP (Rao Sambhasiva et al 1978[47], Mahalick 1996[48], Mohanty et al., 2005[49], Mishra et al., 2021 [50]). The largest Asian lagoon Chilika was a river estuary during Pleistocene. During Northgrippian age, maximum sea level rise and heavy ISM rainfall converted the large low marshy land to a gulf covering a vast area more than 1500km^2 (Venkatratnam 1970[51], Sadakata and Kakani et al., 1993, Sethi and Mishra S P., 2020). The erratic ISM, intermittent very high floods and continuous long spell droughts during early Meghalayan age there was formation of Southern barrier islands and converted the gulf to a lagoon (Khandelwal et al., 2007[54]). The distributaries in the Mahanadi river system have multiple ISM signatures and multi-proxy events in change of courses in the Meghalayan age. Few evidences are dominance of the Burdha, Old Kathajodi, Prachi and Ratnachira system and later weakening and emerging as Devi, Kuakhai, Kushabhadra, and Daya system and many-abandoned channels (Old Kathajodi, Alaka, Prachi, Sunamunhi and Malini etc) during Meghalayan era (Mishra et al, 2021[50]).

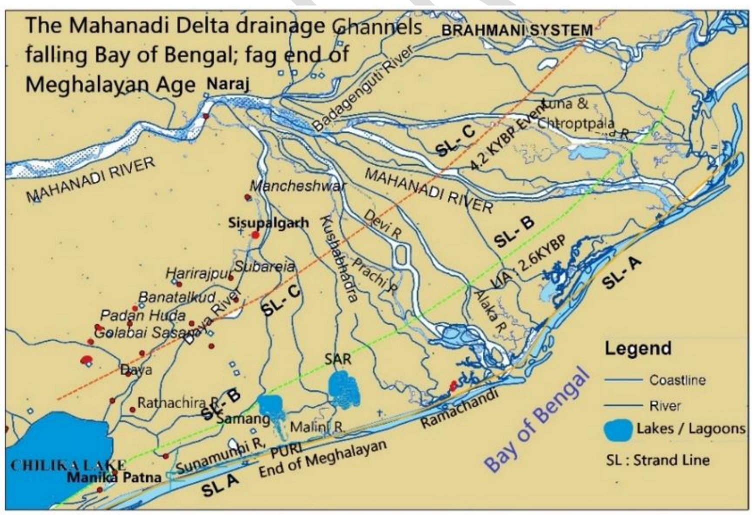


Fig 5: Change in river courses in the Mahanadi delta; due to Hifloods Meghalayan age

Holocene Paleoclimate:

Terrestrial and marine climatic proxies recorded those are sensitive climate changes. Three trend in paleo-climatic signatures established during Holocene. The rise in short-range cold phases called Greenlandian (11.0–8.0 KYBP); stable warm climate named Northgrippian (1.0–3.5 °C above during 8.0–4.5KYBP). The present titled as Meghalayan phase with declining temperature trend, and climatic uncertainties from 4.5KYBP to 71YBP. The proxies reflected from lake levels and vegetation, The Meghalayan stage include abrupt temperature settings like the Medieval Warm Period, the Little Ice Age and the Modern warm period, Borzenkova et al., 2015[55]. Geochemistry studies of Chachi and Luni along west coast of India reveals about two stages of time-based variabilities (4.6KYBP to 2.5KYBP) in vegetation, humidity, and environmental vicissitude and from 2.5KYBP to 70YBP, characterized by less rainfall and enough mesic vegetation (Pillai et al., 2018[56]). Climate reconstructions during the Meghalayan age, classified as forcing of anthropogenic aerosol, sun earth geometry, volcanic eruptions, seismic, GHG gasses and solar irradiance. The reconstruction of late Holocene (Meghalayan sage) in Northern Hemisphere (NH) the anomalies of surface air temperature (SAT), i.e. ice ages and worm periods. Models structured for SAT of paleo climate. The model results reveals that GHG gases rise is responsible for the high SAT temperatures occurred at millennium frequency @0.36 times per 4000YBP for NH temperatures during late Holocene. The global SAT plummeted by Little Ice Age, later rose continuously between AD 1450 and 1850, (Kobasi et al., 2013[57], Mishra et al., 2020[58], Scott 2021[59]).

Inter Tropical convergence zone:

The tropical/subtropical landmass due to solar insolation during summer adds energy to the atmosphere. The energy try to push the inter tropical convergence zone (ITCZ) to lower energy zone shift towards north causing advection of moist and warm air masses from SW-ly direction. The motion of the ITCZ occur towards Himalayan range along with Tibetan Plateau block the advection of dry and cold air masses received from mid-latitude oceans as westerly circulation. The phenomenon called The Ventilation effect that delimits movement of ITCZ further north. Similarly, during post monsoon the westerly disturbances and subtropical highs push the ITCZ towards equator and finally push it to southern Hemisphere during February. The movement and positioning of ITCZ, indicate the intensity of ISM, creation of cyclonic disturbances in NIC, including BoB and A.S. (Ramisch et al., 2016[60], Quamar et al., 2021[61]) **Fig 2 (b).**

Azores High

The persistent and quasi-stationary atmosphere's circulation in N-Hemisphere, the Azores High or Bermuda High is the subtropical anticyclone in Atlantic Ocean positioned (25°N to 35°N) with deep tropical easterlies moving equatorward and mid-latitude westerlies propagating towards pole, that is the pivotal center in the global climate system. On study of inter annual ISM rainfall it is observed gradual shift from west to east and vice versa between NE Himalayas and western Himalayas being influenced by vigorous Bermuda High and triggered by Ross by wave. (Binkley 1987[62], Jadav 2021[63]) **Fig 2(a).**

Indian Summer Monsoon:

The Asian monsoon intensification linked with the Tibetan Plateau uplift consequent upon the impact of collision of the Indian plate with Asian plate ≈50 MYBP (Royden et al. 2006[64] In India, the ISM (Indian Summer Monsoon) prevails in India during June to Sept of the year that give about (75% to 80%) of the annual rainfall of the area. Annual erraticism of ISM rainfall is sturdily predisposed by EL-Nino Southerly Oscillation (ENSO), Indian Ocean's N-S, gradient of sea surface temperature, pIOD (positive Indian Ocean Dipole), boreal summer intra seasonal oscillation (BSISO), El Nino Modoki events and Madden-Julian oscillation (MJO). Present study focusses on the changes in ISM for dry period with mega drought events, that had brought two-century long severe drought and shattered many civilizations in Africa (North), the Middle East, and south Asia **(Fig 6).**

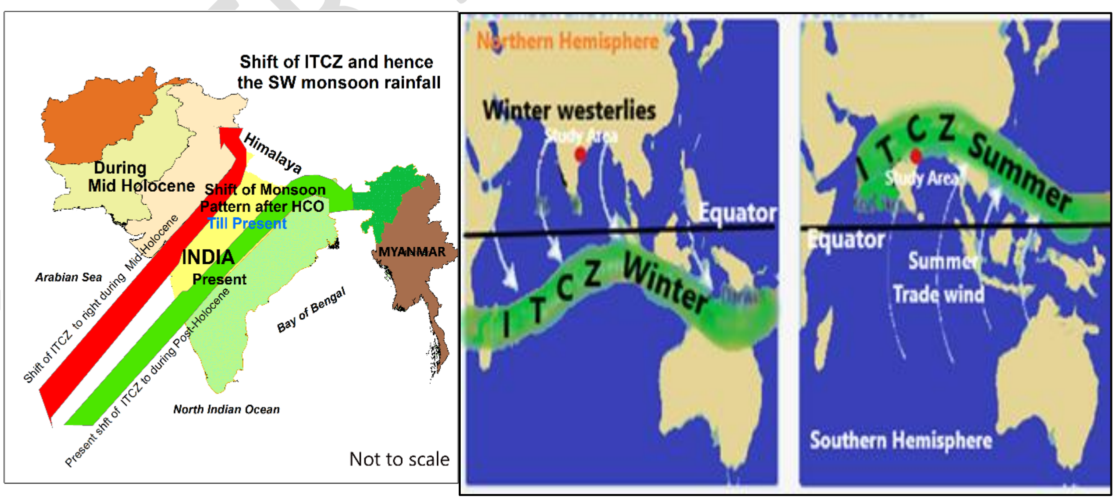


Fig 6: Shift of ITCZ from west to East Fig: 2(b) Position of ITCZ over Indian Subcontinent.
Source: https://scied.ucar.edu/docs/why-monsoons-happen

During Meghalayan age (before 4200YBP), the ISM rainfall was highest in Indus River valley so the Harappa civilization established and grew, later shift of the ISM to central India during early Meghalayan stage brought Sindh civilizations under rain scarce area causing the city to fall. The shift of monsoon from west to east and abnormal shift of ITCZ had changed the monsoon pattern in Indian sub-continent. The records of the isotopic shift reveals there was decrease in monsoon rainfall, Berkelhammer et al., 2012[65]. The uniform growth of logs of C4 plant rings during ≈4.7 to 2.0 KYBP signifies steady waning of ISM with maximum at ~2.0KYBP being the weakest monsoon (Kumar et al., 2019[66]). Forcing factors responsible for shift of ISM, climate variables, and unconventional swing ITCZ. The Little Ice Age, (LIA), India had prevalence of wet conditions in the north, west, and central states. The dry macroclimate occurred over majored part of peninsular India (Banerji et al, 2020[67]).

Changes in RSLR:

Globally subsidence due to glacio-isostatic adjustment (GIA), the mean Regional Sea Level Rise rates from ~6ka to present were 1.4 mm yr−1 marsh records and model results of geophysical model studies (Cronin et al., 2019[68], Yan et al 2021[69]). Kumar, et al. 2021 reconstructed transgression and regression of sea during Meghalayan age. The archaeological findings have established settlements during late Holocene in coastal eastern India (Erenda and Sirjua) but no settlement during Northgrippian, and Greenlandian period. Archeological discoveries of underwater monuments at Mahabalipuram, Vet-Dawrika, Ram Setu at Rameswarm etc

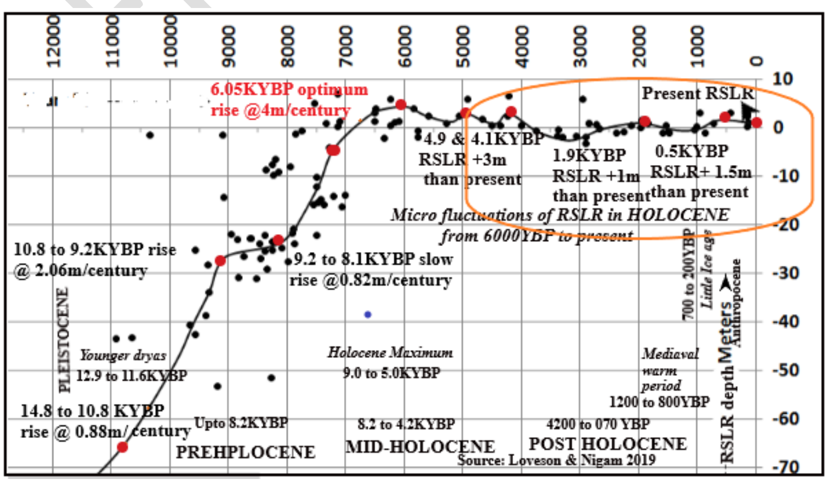


Fig 7: The Holocene RSLR changes with climate proxies (Source mod: Loveson et al 2015[70])

Strand line movement hypothesized during 5.0KYBP but during 4.0KYBP regressive proceedings recorded in east coasts of India. Later transgressive events recoded between 2970±100YBP and c. 3400 YBP along the eastern coast and northern South China Sea (Kumar et al., 2021[71]). The coastal transformations were recorded due to major transgressive event, Farooqui et al., 2000[72] have reported sea-level regression following the major transgressive event at 3150 BCE to 2370 BCE which transformed the geomorphology of the Chilika, Kolleru and even Pulicat Lagoon in AP (Andhra Pradesh) (Jadav et al., 2018, Mishra S. P. 2020[74]). A drop in regional sea level points during the Little Ice Age (LIA) (300-250YBP) **(Fig 7).** The archeological findings from various excavations has left its proxies at Gopalpur, Golabai, Delang (Hariraj Pur), Balasore (Durgadevi and Ranasahi) of Odisha indicates a distinct agro-based economy during Neolithic-Chalcolithic age (Mishra et al., 2021[75]).

Westerly movement in Indian peninsula

During Holocene period, Ladakh had four prominent phases such as ~10,800–10,000YBP; ~8800–8600YBP; long phase of warm aridity climate at ~5200–2600YBP; ~1700–1500YBP and ~500 YBP) interfered by relatively warm climate. Along with ISM, the westerlies advancement had governed the hydro climate of northwestern parts of Bihar, WB, Jharkhand and Odisha India. The westerlies governed during Northgrippian while ISM dominated during Greenlandian age. During mid-Holocene (~3200YBP), Westerlies predominated the ISM. The lake and other records from the region in the years during Holocene—7200, 5200, and 2600 YBP although the westerlies have poured heavily in the Ladakh region latter, (Phartiyal et al., 2022[76]).

Vegetation History Meghalayan age:

The pollen evidence suggests that between ca. 3000 and 2600 YBP, savannah vegetation occurred in the region having a comparative lesser monsoon rainfall. The forest expanded as an open-mixed tropical deciduous forest between 2600YBP and 2200YBP under a warm and moderately humid climate with increase in ISM rainfall.

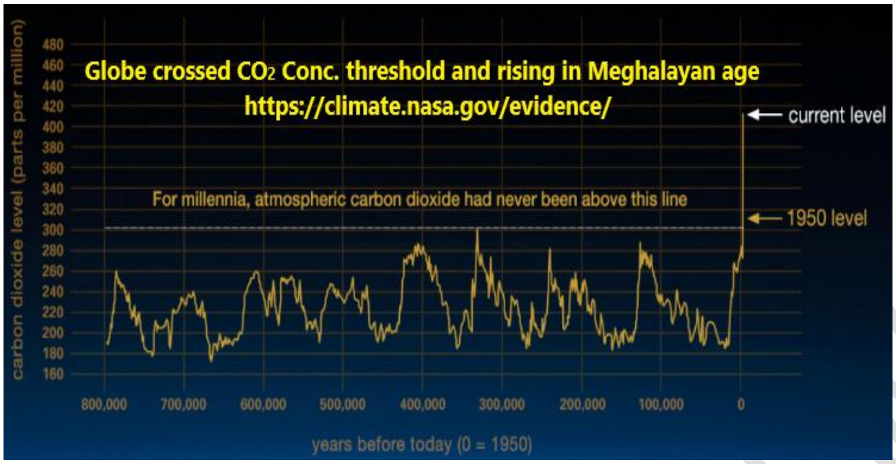


Fig 8 : Rise in CO_2 in atmosphere during the Meghalayan Age; (Luthi, D., et al.. 2008[77])

Later from 2200 - 2000 YBP, the open-mixed tropical deciduous forests in east India and adjoining Himalayas transformed the dense deciduous forests due to swing of the mean path of ISM with rise in monsoon rainfall. Afterwards the gradual warming and the rise of the ISM, (2600YBP to 1850YBP), during the Roman Warm Period (RWP), with intensified human activities, decreased the land use pattern (**Fig 8**).

There was gradual intensification of the monsoon between ca. 2600 and1800YBP, and an increase in the ISM until present warm period. Presently dense mixed tropical deciduous forest has existed under a warm and relatively more humid climate indicating a further increase in monsoonal precipitation but reduced under anthropogenic stress (Bonnefille et al., 1999[78], Quamar et al., 2017[61], Kumar et al., 2019[66], Banerji et al., 2020[67])

Mangrove vegetation:

Palynological studies reveals that salt tolerant Mangroves resistant to saline atmosphere were extending from Kanuru, and Machlipatnam coast until Myanmar coast including Chilika coast during mid Holocene (Khndelwal et al., 2008[54], Farooqui et al., 2016[72]). Researches but sporadic about formation of coastal indicators like those that barrier islands, mangrove, sand dune vegetation, mud flats, and Lagoons reported in literature. Mangroves; reducers of CC stresses, RSLR and drought; cover 0.7% of the global tropical forest area but provide lion's share of ecosystem services by sequestration, Lovelock et al., 2017[79].

Reports available about RSL anomalies during Last Glacial Maximum(26 to 21KYBP), there were MSL rise in ≈130–120m lower than present are the global Quaternary eustatic sea-level cycles The Greenlandian age refers to sea level transgression in BoB coasts. That influenced geospatially the mangrove transgressive segments supplemented by ISM /EASM (East Asian summer monsoon) and variable sediment flow through major inflowing rivers like the Irrawaddy, the Brahmaputra, the Ganges, the Mahanadi systems and the largest Lagoon Chilika associated with various species of mangroves along their estuaries.

Initial phase of Meghalayan age (≈4.2KYBP, and ≈2.6KYBP), considered warm and humid climatic conditions. However, degrading trend in vegetative status reported. After 2.6KYBP, mangroves re-flourished along the BoB coasts until 2.3KYBP, consequent upon relative stability of sea level. The invasion of midland fresh water dry climate taxa, progressions and retrogressions of strandlines along East coast of India and West coast of Myanmar has huge mangrove spread. Present mangrove afforestation has been futile for selection species, RSLR and climatic traumas. The Mangroves plantation tried along Chilika coast last five years but the growth is rarely luxuriant even if tried by CDA near Arakhakuda (Pandey et al., 2014[80], Feller et al., 2017[81], Mondal et al., 2021[82]

Tectonic Subsidence:

The large deltas of the Mississippi, the Rhine, the Rhône, the Danube, the Nile, the Amazon, the Tigris-Euphrates, the Ganges, the Mahanadi, the Godavari and the Indus, were under tectonic subsidence. The major Tectonic Zones (TZ) are at Himalayas (East to west), Assam-Arakan, Baluchistan-Karakoram, Andaman-Nicobar and Unwavering Continental Regions (Zone V). The river basins of India, Myanmar and other countries surrounding Bay of Bengal are sedimentary. The East India shield margin comprised of vigorous tectonic activities in past along the Shillong plateau, Eastern Ghats, Chottanagpur plateau and the Southern Granulite Terrain (SGT). The Indian plate had easterly subduction between the Burma microplates as the core of the tectonic activities... The Indo-Burman ranges remains northerly and form the Naga Hills trending SW-NE. The result was the (IBCZ) Indo-Burman convergence zone associated with continuous tectonic activities and landslides undergoing subduction continuously along Shillong Plateau and Mikir Hills. The Tripura fold with associated thrust resulted the forehead basin along the Bengal Basin, Biswas et al., 2014[83], Kumar et al, 2015[84].

Transformations in deltas

During Meghalayan age, the deltas of the lower Ganges, the Mahanadi tri-delta, Subarnarekha delta along with the Golabai Sasan and Ramchandrapur within Chilika basin changed their morphologic, and eustatic sea level during the Meghalayan Holocene. Modifications in the coastal geomorphology observed in anastomosed drainage pattern, estuarine configurations, tidal inlets, along with sinking and shrinking of the lakes and lagoon, sedimentations, and marine transgression (change in strandline). Dating back from 4.2kYBP to 2.1kYBP (the Chalcolithic phase, Iron age), there is archeological evidences along deltas of the Mahanadi Odisha and the Chilika coast (Kingwell et al., 2018[85], Mishra S. P., 2018[86], Hazara et al, 2020[87]).

End of Indian Civilizations:

In past, major civilizations (Harappa or Mahenzo-daro) built up along Indian subcontinents either in alluviums, flood plains or delta's of Sindh or Ganga rivers during pre and mid Holocene epoch. The collapse of those civilizations presumed due weak ISM, East Asian summer monsoon (EASM) and high solar insolation's during early part of post Holocene based on many climatic proxies and paleo-climatic records,(**Table 2**), Cheng et al, 2021[88].

Table 2: Societal and technological growth of people during late Pleistocene in Indian subcontinent

Period Name	Climate condition	Human popul^{n}	Societal/ technology development	Sites as Microliths
Paleolithic period (2MaYBP-10KYBP)	Extreme cold; Younger Dryas	<0.1mn Homosapiens; Stone age	Fire, Tools of stones, Ostrich Egg; Hunter gatherers; caves life, Saber-toothed tigers and cave lions	Bhimbetka(M.P),Hunsgi, Kurnool Caves, Narmada Valley (Hathnora, M.P), Kaladgi R., Mehergarh
Mesolithic Period; (10- 8.2 KYBP)	Major CC: Cold; glaciation	Green landian <1mn people	Agriculture, Cattle fostering); stable life; Mining, melting; casting; Dentistry	Brahmagiri (Mysore), Narmada, Vindya, Gujarat; Indus and Gangesvalley;
Neolithic Period	Warming started after	North-grippian	Primal Agro-based village, Ayurveda	Burzahom, Gufkral (J&K), Mehrgarh Indus valley)

(8.3-4.2 KYBP)	the Ice age; Plague of Justinian (pandemic)	(Megalithic) ≈1million	knowledge wheels cremation over burial; Flush toilet; Pepper in cooking; Kingdom & rullers; weighing scale	,Chirand (Bihar), Daojali Hading (Tripura), Koldihwa (UP), Mahagara (UP), Hallur & Paiyampalli (AP), Maski, Kodekal, Sangana Kaller, Utnur, Takkala Kota.
Chalcolithic Period (4.2-3.6 KYBP); Early Vedic period	Abrupt shift cooler to drier climate	Meghalayan; Bronze age; ≈6Mn people	Indo-Aryan Exodus Glass making; & Fall of Indus valley culture, Ganges plain evolution; Plastic surgery	Brahmagiri, Navada Toli (Narmada region), Mahishadal (W.Bengal), Chirand (Ganga region); Golabai & Harirajpur (Odisha)
Chalcolithic Period (3.6 -2.6 KYBP);Globally Medieval warm period) Megalith Culture; Jain & Buddh-ism;	ITCZ Shift Indus valley to Ganges Plain	Meghalayan; Iron-age India (Vedic- Upa-nisad);≈25Mn people	Influx Aryans; Boat making; Medicines; hand propelled wheel, Cemetery H culture ;Extraction copper Arravali Hills; Bronze alloy from Ambaji	Karim-Shahi (Gujurat); Sisupalgarh, Manik Patna Talapada, (Odisha); Atara njikhera (Etah), ,Sunet Punjab; Parsvanath,, Mahajanapads Ancient civilization; like China, Egypt & Greece
Classical era; 2.6KYBP-800YBP (vedic age) Excellency in Iron works	Gupta Kingdom (300AD – 800AD): Classical Period	Meghalayan (Early medieval)	Science developed (Math, Astronomy & medicine); Kingdoms /Nations; wootzsteel (south India); Iron pillar Delhi.	Mauryan Period, Chola, Chera, Pandyas, Sakas, Kushanas; Gupta kingdoms plague, smallpox / measles (≈36mn lives)
Pre Christian era 1200YBP-0300YBP	Moghul Period	Late Medieval India	Pyrotechnic works; Rise Islam/ Sufism; Textile, weaving &	Many temples; Books writing; Gunpowder use in wars; Plague/black death,

			dying; Mansabdari/ Land Revenue System: Bandobasta; Babarnama (flora/ fauna); Ain-i-Akbari; crops, plants, fruits of central Asia; Europe	malaria, dysentery, flu, diphtheria, smallpox typhoid, leprosy, took 200mnlives; portraits paintings; Indo-Islamic architecture excellence. Tajmahal; Quetubminar etc
British era (1700 to 070YBP)	British rule	Pre-independence	Cosmetics/Perfumes; Dalton minimum 1800-1820; New technologies; Good ISM; Lagoons squeezed; Industrial revolution, good rain, High rise population; less storms/disasters	Great Bengal famine; Cholera; Plague; Yersinia pastis bact. H1N1 Pandemic; fire guns; Urbanization,

Source: https://www.clearias.com/indian-history-chronology/; https://humanjourney.us/ideas-that-shaped-our-modern-world-section/early-civilizations-harappa/;http://www.igntu.ac.in/e Content/IGNTU-eContent-374229503877-BA-AIHC-6-DrJanardhanaB-ScienceandTechnology in Ancient India -3.pdf

Discussion:

The stalagmites in caves that restructure temperature anomalies from cave carbonates, the changes in the δ18O values and the triple oxygen isotopic composition can predict their age (Laskar et al., 2021[89]). The rapid climate changes (CC) has invited during the Meghalayan age has invited global warming with rise in SST and SAT, Ice sheet melting in glaciers, reduced polar ice sheet, MSLR/RSLR, Carbon sequestration, Extreme events, ocean acidification and many others (Nerem et al., 2018[90]).

The hunter and gatherers of pre-Holocene started staying in river valleys with nucleated settlements with primary source of livelihood as agriculture (stable and favourable SW monsoon), and hunting as the 2ndary profession during late Holocene period (ca. 4.0–2.6KYBP).

Paleontological archives like Copal and resins along with historical evidences framed to construct biostratigraphy. Primal forests like Madagascar, East Africa, and Colombia resins, ambers studied and the declaration of Meghalayan age (4.2KYBP to 1950 AD) was questioned as a quick decision by the International Commission on Stratigraphy (ICS),(Solórzano et al., 2020[91]).

There was significant ISM anomalies during 4.2.K event for mentioned 200years (4.3 to 4.1KYBP) i.e. at the beginning of the Meghalayan age. The key players and driving forces can be down trend in solar insolation, prevalence of cooling phase in the North in higher latitudes, erratic movement of the ITCZ from peninsular India to eastern part of Himalayas, Dominance of westerlies, prolonged La-Nina, weak ENSO, dominance of NIoD, and finally retrograding of Bay of Bengal with RSLR fall.

However Dutta et al., 2021[92] reported about a transition period of one millennium dry phase over Indian subcontinent between Northgrippian and Meghalayan age. Nevertheless, the 4.2KYBP drying event have dominance over NW-India whereas some parts of the Indian peninsula and eastern Himalayas received heavy rainfall, high floods, that helped in formation of Speleothem Stalactites and Stalagmites in the caves of Khasi Jaintia calcareous rock masses of Meghalaya . It was due to influence of long activity of the ITCZ in eastern foothills of Himalayas.

Scroxton et al., 2020[93] reported that there were two prominent drought spell during pre-Meghalayan era. The first spell was abrupt 300-year long westerlies based with giving precipitation during winter months, (i.e. 4.26 and 3.97KYBP, associated with the 4.2KYBP event as per paleo hydro-climate studies.

Rasmussen et al., 2007[4], Walker 2018[5] claimed the classification of tripartite Holocene age as Greenlandian, Northgrippian and Meghalayan based on ice core proxies and Speleothem fabrics in the last 20years has been ratified by Philip Gibbard of Cambridge University (Hindusthan Times on 1st Feb 2022) and incorporated by International Union of Geological Sciences (IUGS).

The tagging of the stalagmite has now been tagged a Global Boundary Stratotype Section and Points (GSSP) but yet to be stamped.

Conclusion:

The multi-proxy records of archeological findings, ISM shifts, Holocene paleo climates, Pollen records, Speleothem findings reveals about sustainability of civilization is dependent on stable hydro-climate. The study of texture profiles for stalagmite best preserved documentation in constructing geological ages. The palynofacies at lime rocks are the calibrating tools of bio-stratigraphy. The research gap in designation of the stratigraphy towards fag end of the Holocene epoch was less explaining. The relative elevation due to, sediment flow, mineralogical, and geochemical features and paleontological proxies discovered in the Lakadong Limestone of Triassic period of Mawmluh cave of Meghalaya, has made the ratification process simple along with ice core records of DYE-3, GRIP, NGRIP1, NGRIP2 and GICC05 at Greenland and officially stamped by The International Commission on Stratigraphy (ICS). From the multy-proxies, bio-stratigraphy and Radionuclides the established Greenlandian age from 11.7KYBP event, Northgrippian age from 8.2KYBP event and the Meghalayan age from 4.2KYBP event during the Holocene epoch.

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