Department of Earth Sciences **November 24, 2012**
Graduate 9580/9680 **BGS Rm 1056**

Geology and Geophysics Graduate Symposium

Time	Speaker	Title
9:00 am	Annemarie Pickersgill	Shatter cones: A diagnostic feature of hypervelocity impact.
9:12 am	Tanya Harrison	Geologic activity on Enceladus.
9:24 am	Anna Nuhn	Martian, Lunar, and terrestrial cave entrances: A comparative geological analysis.
9:36 am	Eric Pilles	The mantle plume paradigm.
9:48 am	Mahadia Ibrahim	Asteroid mining: Possibilities and challenges.
10:00 am	Cassandra Marion	Volcanism on Io.
10:12 am	Patrick Shepherd	Common causes of colour in natural diamonds: Dislocations, impurities, and vacancies.
10:24 am	Renata Smoke	Formational models of Au-rich volcanogenic massive sulfide deposits.
10:36 am	------------------------------------ *Coffee Break*	---
10:48 am	Yonghua Cao	Convergent margin-related orogenic belts and metallogenesis.
11:00 am	Randy Campbell	Carbonatites: A classification and evolutionary review.
11:12 am	Gloria Eboremen	Bioremediation of petroleum hydrocarbon-contaminated soils: Land farming approach.
11:24 am	David Olutusin	Formation of black shales: Deep versus shallow water interpretation.
11:36 am	Colin Terry	Determining igneous structures and geomagnetic field history from induced and remnant magnetic fields.
11:48 am	Tola Ogunniyi	Resource potential of the Barnett Shale, Fort Worth Basin, Texas.
12:00 noon	Wesley Greig	The precession of the perihelion of Mercury.
12:12 pm	Mansour Al-hashim	Stromatolites: Utility, application, and challenges.
12:24 pm	------------------------------------ *Lunch Break*	--
1:24 pm	Roderick Tom-Ying	Microfossils and the origins of life on Earth.

1:36 pm	Kathryn Lapenskie	Affects of Early to Middle Ordovician climate, paleogeography, and environment on faunal radiation.
1:48 pm	Elizabeth Hooper	Recognition of tsunami deposits within the sedimentary record: Attempts at establishing a tsunami facies.
2:00 pm	Filippo Resente	A comparison of two projects for the prevention of high water in Venice, Italy, as a result of land subsidence and climate-induced sea level rise.
2:12 pm	Tara Despault	Effects of climate-induced temperature and water table changes on carbon dynamics of northern peatlands.
2:24 am	James Goacher	Millennial climate cycles in the Holocene.
2:36 pm	Mengmeng Qu	Strength of the continental lithosphere.
2:48 pm	Weiyin Chen	Shale gas in Canada: Geological controls and current challenges.
3:00 pm	------------------------------------ *Coffee Break* --	
3:12 pm	Alana Crump	Groundwater remediation using zero-valent iron as a reactive medium in permeable reactive barriers.
3:24 pm	Sean Fulcher	Mining salt, brine and clay: A review of lithium and boron evaporite deposits.
3:36 pm	Xiaoming Zhang	Self-organized criticality: what can it tell us about natural hazards?
3:48 pm	Tararat Lerkwieng	Basin controls on the occurrence of reservoir intervals in the Cardium Formation, Alberta.
4:00 pm	Yelena Kropivniskaya	Seismic risk in Canada.
4:12 pm	Behzad Hassani	Uses and challenges in real-time seismological data applications.
4:24 pm	Jonathon Hey	Detachment faulting and it's implications of the mineralization of oceanic core complexes.
4:36 pm	Sean Funk	Models and timing of core formation.
4:48 pm	------------------- Thank you to everyone for attending! ---	

Please join us for four more presentations on Monday November 26, 9:30 am in BGS 1053

Sarah Sweeney	Dominant gliding versus pure spreading in passive margins: The effect of differential sedimentation on initiating salt tectonics.
Martin Arce	Weathering-induced metal-enrichment processes.
Wajahat Ali	Geophysical techniques for shallow subsurface Ground Penetrating Radar (GPR), Multi-channel Analysis of Shear Waves (MASW), seismic refraction and reflection.
Hadis Samadi Alinia	Database for flooding susceptibility, hazard, and vulnerability assessment.

Shatter Cones: A Diagnostic Feature of Hypervelocity Impact

Annemarie E. Pickersgill

Shatter cones have been an important tool in the identification and study of impact structures on Earth. Most terrestrial impact structures have been heavily eroded, as a result the features which make them readily identifiable on other rocky planetary bodies disappear. This, in addition to the propensity of circular structures of endogenic origin has made the identification of terrestrial impact structures difficult. It is therefore useful to have a unique indicator of shock that is readily identifiable in the field. Shatter cones are the only macroscopic feature that is indicative of shock deformation and therefore diagnostic of hypervelocity impact. They form in large volumes of target rock, and at depth, so they are widespread and often still visible after erosion of the upper part of the structure. An impact origin has been confirmed based on the presence of shatter cones alone, but more often the discovery of shatter cones is followed by a search for microscopic shock metamorphic effects. Shatter cones are found only at impact structures and nuclear test sites, and until recently, only on Earth.

Shatter cones are roughly conical, curved, pervasive fractures characterized by multiple sets of striations that radiate and branch away from the apex. The acute angle of intersection of the striations tends to point toward the apex of the cone. Partial cones are more common than full cones, and the apex of a cone is rarely seen. Smaller "parasitic" cones formed on the surface of larger cones are common, creating a composite texture. Shatter cones range in size from several millimetres to metres. *In situ* shatter cones have been found individually but are far more common in groups, often with roughly parallel axes and with apices pointing in a similar direction. The general direction of orientation is "inward and upward" when beds are restored to pre-impact position. However, cones with highly variable orientations have also been observed in outcrop and hand specimen.

Shatter cones are best developed in fine-grained lithologies, and poorly developed in coarser grained rocks. Crude shatter cones are flatter, and have larger striations that can easily be mistaken for other features such as slickensides, cone-in-cone, wind abrasion features, and anthropogenic blast cones. The most obvious differentiating feature is the penetrative nature of the fractures – if you break a shatter cone it will tend to fracture along other shatter cone surfaces. Microscopic shock metamorphic effects such as planar deformation features and diaplectic glass have been documented in shatter cones, though their presence is not ubiquitous. Similarly localized melting along shatter cone surfaces has been found in some, but not all, samples.

The formation of shatter cones is still poorly understood. Target lithology does not seem to have a large effect on whether or not shatter cones form, only on their quality. Models, experiments, and field studies indicate that shatter cones form immediately as the shock wave passes, at relatively low shock pressures (~2-10 GPa, rarely up to 30 GPa), and prior to excavation of the cavity.

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The Geomorphology of Enceladus

Tanya N. Harrison

Saturn's moon Enceladus, while small enough to fit within the state of Colorado, has garnered the attention of the astronomical and planetary science communities even before any images of the body had been acquired. Ground-based telescopic observations revealed an unusually bright body orbiting within the brightest portion of Saturn's diffuse E ring, leading to the suggestion that Enceladus was a primary source of E ring material. However, the mechanism by which Enceladus could be contributing enough material to account for the observed brightness was unknown. The arrival of the Voyager 1 and 2 spacecraft to the Saturnian system brought about some new understanding of Enceladus with the return of the first photographs of its surface. These photos showed a striking dichotomy, with an older, heavily cratered northern hemisphere and a younger, relatively crater-free southern hemisphere cut by multiple tectonic features. The formation of the tectonic features was attributed to tidal forcing from Saturn and a 2:1 resonance with Dione leading to compressional and extensional stresses. The crater density in the smooth southern region implies that it is nearly the youngest of all the icy satellites in the solar system, third only behind Europa and potentially the polar regions of Triton. How this region was being resurfaced was still unknown from Voyager data. It was not until the arrival of the Cassini mission that the questions of the mechanisms for both resurfacing and E ring contributions would be answered. Cassini observed multiple water ice plumes being ejected from high-temperature (180 K or more in some cases) regions associated with "tiger stripe" fissures in the south polar region. This paper details the progression in our knowledge of the geomorphology Enceladus from the pre-Voyager era to the revolution brought about by Cassini.

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9:24 am

Martian, Lunar, and Terrestrial Cave Entrances: A Comparative Geological Analysis

Anna Nuhn

Large-scale igneous provinces are found on both the Martian and Lunar landscapes which make for excellent environments for near surface basaltic lava tubes and associated atypical pit crater formations. Models of lava tube formation typically involve the outer surface of a lava channel cooling more rapidly consequently forming a hardened crust; the remaining lava flows out of the tube, leaving a void space. Models for atypical pit crater formation include collapsed lava tubes, dilational faulting, dyke swarms and collapsed magma chambers, all acting as subsurface voids for surface collapse. Near surface basaltic lava tubes and associated atypical pit craters have recently been known to possess cave-like entrances on the Moon and Mars, called "skylights".

Caves on Mars and the Moon have been hypothesized since the late 1960s, but not until recently these planetary structures were discovered. This paper will review newly observed lunar skylights in Marius Hills, Mare Tranquillitatis, and Mare Ingenii along with Martian skylights in the flanks of Pavonis, Ascraeus, and Arsia Mons, and flows from Hadriaca Patera. Observations of these entrances have been done using a suite of improved orbital high-resolution imagery and thermal infrared detection methods of the subsurface geology. For Mars these instruments include, the Mars Odyssey's Thermal Emission Imaging System (THEMIS), the Mars Reconnaissance Orbiter's Context Camera (CTX) and High Resolution Imaging System (HiRISE). On the Moon, KAGUYA SELenological and Engineering Explorers'(SELENE) Terrain Camera (TC) and the Multi-band Imager (MI), as well as the Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) are being utilized.

These extraterrestrial cave entrances pose as ideal spaces for future robotic exploration, mineral and astrobiology investigations, as well as potential human bases in planetary missions. Understanding cave entrance formation on Earth is critical for understanding the development and exploration possibilities on other planetary bodies. Terrestrial analogue sites including the Atacama Desert in northern Chile, Teide National Park in Canary Islands Tenerife, Spain, and Kazumura Cave in Kilauea, Hawaii, will continue to serve as locations for the development of scientific exploration strategies and new technologies for future Matian and Lunar missions.

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The Mantle Plume Paradigm

Eric Pilles

Modern mantle plume theory is incomplete. Numerous publications dispute portions of the theory, while others have raised the question if mantle plumes exist at all. Alternative theories have been produced which directly relate to plate-tectonic mechanisms and completely disregard mantle plume theory. When considering the evidence, from both sides of the argument, it is clear that while the current mantle plume model is incomplete, it is superior to alternative theories presented by the "Antiplume Lobby".

The current mantle plume model defines mantle plumes as a spatially fixed upwelling of hot light material that ascends from the core-mantle boundary. The theory states that the plumes themselves are stationary while the plates above them move freely.

There are several objections to the mantle plume theory. First, geochemical indicators such as $^{3}He/^{4}He$ are often used to indicate origin from the mantle-core interface. However, large-scale mixing of the lithosphere and mantle - via subduction and convection - result in chemical heterogeneity of the mantle. Mantle plumes are not always associated with an uplift of the Earth's surface, for example at the Siberian flood basalt province, the submarine Ontong Java Plateau, and the Decan traps. The statement that plumes are stationary has been proven false. Displacement has been observed in both the head and tails of plumes. Additionally, the anomalously high temperatures necessary for melting under dry conditions would be accompanied by increased heat flow above the plume, however this is not seen.

Alternative theories suggest that the 'plume' feature is attributed to plate tectonic mechanisms and appear as a result of shallow tectonic stress, subsequent decompression, and melting of the mantle enriched in basaltic material. However, these theories fail two address two major problems – problems which the mantle plume theory can explain. Time-progressive volcanic chains, such as those at Hawaii, a classic example of mantle plumes, cannot be explained by alternative theories such as crack propogation – while mantle plume theory explains not only the general behaviour of volcanic chains, but also many details related to plate motion in these regions. Additionally, alternative theories involve passive plate tectonic mechanisms, which take place in the lithosphere and upper asthenosphere, while seismic tomographic data has shown that plumes can extend into the mesosphere. Therefore, while many answers remain unanswered, the mantle plume theory still remains the most accurate model to date.

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9:48 am

Asteroid Mining: Possibilities and Challenges

Mahdia Ibrahim

Asteroids represent the remaining building blocks from the early Solar System formation ~ 4.6 billion years ago. Most asteroids have retained a relatively pristine record of nebular and early planet-forming processes that provides clues about Solar System dynamics and orbital evolution. Improved remote observations, the science of meteoritics, and multiple flyby and rendezvous missions have provided much of our knowledge on asteroid regoliths, their mineralogical composition and physical properties. Detailed analysis of a number of meteorite samples showed relatively high concentrations of valuable metals by Earth standards; including platinum group elements, Rare Earth Elements (REE) and gold. Asteroid mining may lead to economic gains and scientific outcomes that will contribute greatly to the state of human civilization on Earth and beyond.

The idea of the possible exploitation of asteroidal resources of minerals and REE is not new (early 1900's), but substantial data about the composition and surface properties of asteroids were unavailable at the time. Today, science data and technology necessary for asteroid mining are becoming available. Assuming that enough knowledge has been acquired on asteroids' properties, mining remains a challenge for many reasons that could be summarized in three areas: 1) economic feasibility and market demand; 2) (NEA) target selection and orbital dynamics; and, 3) mission design and operations.

While successful mining of asteroids have the advantage of obtaining resources without losing energy in huge gravity wells such as on the moon, the cost of mining might still outweigh the desired economic outcome. This has been addressed by suggestions of the utilization of products in low-Earth-orbit (LEO); on lunar bases or future space stations, which could provide an excellent market as contractors and operators in LEO will utilize the material and cut down further costs of transportation. From a science and engineering perspective, a suitable target would ideally be from the near-Earth Asteroid (NEA) population with low inclination to reduce the costs of launch and recovery. Moreover, asteroids are dynamic and extreme environments in terms of temperature, radiation, and physical characterization (e.g. rubble pile asteroids), which requires creative and unconventional technology different than what is known in terrestrial mining. Mission design will require anchoring securely to a "moving object, extracting material depending on lithology (fragmentation on silicate lithologies versus vaporization on hydrated lithology), followed by the challenge of material storage and transportation. This leads to suggestions of robotic capture and retrieval of asteroids to near-Earth orbit, where in-situ utilization can be conducted, thus efficiently cutting down the cost of mining and gaining control of near-Earth objects (NEOs) for multiple purposes including development of asteroid deflection technology.

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10:00 am

Volcanism on Io

Cassandra L. Marion

This manuscript examines the current state of knowledge of volcanism on Io. Io is Jupiter's closest Galilean satellite and the most volcanically active planetary body in the solar system. Unlike all other planetary bodies in the solar system, it lacks evidence of impact cratering, indicating a young surface. Remote sensing techniques applied through the use of ground-based observations and fly-by missions, such as Voyager and Galileo, have recorded spectacular images and spectral data that have led to exciting discoveries. Io's global heat output is estimated to be 25 times greater than Earth, at 10^{14}W. It isunique in the solar system in that its primary internal heat source is tidal heating. Due to its Laplace resonance with neighbouring moons, Ganymede and Europa, energy is dissipated internally, melting a large amount of the interior. The extent of melting and mechanisms of heat transfer within Io are uncertain, however based on its bulk density studies have shown that Io is a differentiated body and likely has an iron or iron sulfide core.

Eruption styles on Io range from flow-dominated to explosion-dominated to intra-patera volcanism. These occur in the form of lava flow fields, lava fountains and lava lakes to explosive, volatile-driven, umbrella-shaped plumes of gas and dust ejected several hundred metres high. Io's tenuous atmosphere is formed primarily by plumes. They occur either in numerous smaller plumes, which are produced near the margins of active lava flows by interactions with near-surface to surface SO_2 ice, or as giant plumes that can reach >200 km high. The dominant volatiles on Io, driving explosive volcanism, are sulfur and sulfur dioxide. There is little evidence of effusive sulfur volcanism, but much of Io is blanketed in SO_2 snow from plume fallout. Eruption temperatures indicate Io's dark lava flows are mafic to ultramafic in composition. However eruption temperatures may not be reflective of liquidus temperatures of the magma, due to either super-heating during magma ascent to the surface, rapid-cooling once extruded, or both. Future missions will further investigate the unknown features and processes on Io.

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10:12 am

Common causes of colour in natural diamonds: dislocations, impurities, and vacancies

Patrick Shepherd

Diamonds are crystalline carbon, which are extremely valuable as gemstones due to their hardness, fire and brilliance. Diamond gemstones alone generate an annual ~\$2x10^{10} USD, excluding diamonds used for industrial purposes. The general public typically thinks of diamonds as colourless, while in fact the most valuable diamonds are coloured. Diamonds with desirable colours are referred to as having a “fancy colour”, and are typically deep shades of blue, pink, yellow, purple, green, and red. Due to the value of coloured diamonds, much research has been put into understanding the source of the colour, especially in light of artificially-produced diamonds with high-pressure – high-temperature (HTPT) treatments altering colour. Blue diamonds are both associated with boron impurities in the crystal structure, whereas yellow is caused by nitrogen (N2 or N3) or hydrogen. Purple, pink, and red are all associated with dislocations, or vacancies, associated with plastic deformation of the crystal. Green colour can be attributed broadly to two main causes: irradiation by gamma-rays (GR1), or nickel impurities. Brown diamonds have recently become an area of interest, because it is now possible to remove the colouring with HTPT treatments, significantly increasing the value of the gemstones. The general consensus is that the brown colouring is caused by plastic deformation, although this remains controversial. It is also debated whether the brown colour was formed before deposition in the upper mantle or during ascent within the kimberlite pipe. The lack of a consolidated review of the origin of colour in diamonds has left hypotheses difficult to compare to one another.

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Formational models of Au-rich volcanogenic massive sulfide deposits

Renata Smoke

Volcanogenic massive sulfide (VMS) deposits include: volcanic-associated, volcanic-hosted, and volcano-sedimentary hosted massive sulfide deposits; and are major sources of Zn, Cu, Pb, Ag, and Au; and significant sources of Co, Sn, Se, Mn, Cd, In, Bi, Te, Ga, and Ge. Gold-rich VMS deposits form a unique subset of VMS deposits, and, like typical VMS deposits, are found: in sub-marine volcanic terranes with compositions ranging from mafic bi-modal to felsic bi-modal to bi-modal siliciclastic; and in rifted arc, back-arc basin, and back-arc rift tectonic settings; and are formed by metal bearing hydrothermal systems. They are defined as Au-rich if the average gold content (g/t) is greater than the combined grades of Cu, Pb, and Zn (in wt. %) and are grouped according to metallogenic association and style of mineralization. These include: A) Au-Cu deposits; B) pyritic Au deposits; and C) Au-Zn-Pb-Ag deposits. In Au-Cu deposits the mineralogical hosts to gold include native gold, Au tellurides, and auriferous pyrite; there is also a spatial correlation with advanced argillic alteration mineral assemblages (kaolinite and pyrophyllite). In pyritic Au deposits gold occurs as inclusions in arsenic-rich pyrite and arsenopyrite, and in massive pyrite zones that are low in base metal content. In Au-Zn-Pb-Ag deposits electrum, pyrite, and arsenopyrite commonly host the gold mineralization, and there is an association with feldspar alteration or gangue minerals. There are two main formational models for this deposit type: 1) syn-deformational overprinting of Au-poor base metal mineralization by metamorphic fluids; and 2) syn-volcanic mineralization by anomalously Au-rich fluids. Evidence of syn-deformational structural controls on mineralization include the location of deposits in deformed sequences proximal to regional-scale faulting and a discordant orientation of sulfide veins to regional foliation. Evidence of syn-volcanic mineralization by fluids with an anomalous chemistry include relatively un-deformed ore bodies, elevated Au concentrations over intervals greater than tens of meters, and observed cross-cutting relationships. Deposit groups classified by base metal content, Au-Cu and Au-Zn-Pb-Ag deposits, and their alteration assemblages are representative of low and high sulfidation fluids, respectively, which is analogous to hydrothermal fluid types which form epithermal type gold deposits. These formational models have been derived from studies done on, and can be applied to well-known deposits including the Archean LaRonde Penna Au-rich VMS deposit (low sulfidation), the Eskay Creek Au-Pb-Zn-Ag deposit (high-sulfidation), and the Horne Au-rich VMS deposit (Au associated with pyrite). The close distribution of Au-rich deposits to typical Au-poor base metal VMS deposits highlights the importance of understanding of formational processes to predicting the location of potential and yet undiscovered ore deposits of this type.

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Convergent margin-related orogenic belts and metallogenesis

Y.H. Cao

Orogeny refers to forces and events leading to a severe structural deformation of the Earth's lithosphere due to the engagement of tectonic plates. The research of orogenic belts which are characterized by pervasive folding belts and active tectonic zones is significant since they have the potential to represent the most favorable producing areas for mineralization because of magmatic activity, faults, metamorphism pervasively took place there. In general, two genetic types including convergent-related and intraplate-related orogenic belts are recognized, in which the former orogenic belts are more essential and will be only involved in this paper. Convergent orogenic belts are further classified into continental collison-related, arc-related and accretionary orogenic belts. Continental collision occurs at convergent continental boundaries, producing mountains and suturing two continents together. Arc related orogenic belt refers to the collision between arc and continent, arc and arc, etc, and arc-continent collisional orogenic belts will be emphasized greatly here because of its remarkable role in mineralization. Accretionary orogens are the sites of long-lived convergent margin tectonics and share some similarities with collision-related orogenic belts, however, accretionary orogenic systems are represented by accreted island arc sutures and are formed in the ongoing convergent plate lasting much longer without disruption by collision. It is suggested that all these three orogenic belts would experience varied stages or geological events when considering their relationships with metallogenesis, i.e., main-collisional period, late-collisional period and post-collisional period for continental collision-related orogenic belts, constructional stage, orogenic stage and late-orogenic to post-orogenic stage for arc related orogenic belts and active subduction-related arc magmatism, superimposed rifting, inverted retro-arc pericontinental rifts, superimposed hot mantle upwellings for accretionary orogenic belts. Metallogenesis varies among different types and stages of orogenic belts is concluded and the reasons may mainly lie on diverse magma systems and fluid systems generated within related tectonic movements. In general, some magmatic hydrothermal polymetallic, porphyritic deposits and/or MVT deposits and W-Sn deposits are formed in continental collision-related orogenic belts as well as arc-related orogenic belts, however, compared with collisional orogenic belts, epithermal deposits and orogeny gold deposits are more typical in arc-related orogenic belts. Metallogenesis in accretionary orogenic belts is typically associated with gold deposits, mainly are porphyry and associated high-sulphidation epithermal Au-Cu-Ag deposits, classic low-sulphidation Au-Ag deposits, orogenic gold deposits, etc.

Keywords: orogenic belt , metallogenesis, convergence, accretionary

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11:00 am

Carbonatites: A Classification and Evolutionary Review

Randy Campbell

Carbonatites were first thoroughly investigated in the late 1950's (Campbell Smith 1956; Precora 1956), and ten years later by Tuttle & Gittins (1966) who proposed some of the most problematic concepts regarding their origin. With limited advancement in the last fifty years the debate still lingers. The current scientific stalemate is in part due to the lack of extrusive carbonatites representative of their parental magmas. That being said, all carbonatites are not created equal. Currently, the IUGS classification of carbonatites allows for a wide spectrum of mineralogically and petrologically diverse rocks. This broad classification scheme requires further subdivision of carbonatites into categories that relate both their mineral chemistry and petrogenesis. This diversity has been noted by Mitchell (2005) who separates carbonatites into two groups: primary carbonatites and carbothermal residua. This review paper looks to develop a thorough understanding of their origin(s) and classification; their association with various rock types of different tectonic evolutions indicates multiple emplacement mechanisms. Using this evidence it may be possible to determine if carbonatites are sourced from a primary carbonated mantle, a result of silicate-carbonate melt immiscibility, or both. Presently there are two prime field locations where effusive carbonatites can be studied. Both Shombole (nephelinite-carbonatite) and Oldoinyo Lengai (natrocarbonatite) in East Africa indicate evidence of liquid immiscibility. This evidence is well documented and has been confirmed experimentally, others such as Harmer & Gittins (1998) would argue that εSr-εNd isotopes conclude that liquid immiscibility is not possible. It has also been shown experimentally that primary carbonatites can be generated from high magnesian melts with a total alkali content of 5-7 wt% (Harmer & Gittins, 1998). Realistically it is not possible to generate one model that satisfies the full spectrum of carbonatites. With further research it may be possible to distinguish between models, providing insight into these poorly understood magmatic/hydrothermal processes.

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11:12 am

Bioremediation of petroleum hydrocarbon-contaminated soils: Landfarming approach

Gloria Eboremen

Abstract: Bioremediation is a full-scale remediation technology which involves the use of use of micro-organisms to remove contaminants from the environment. It is broadly applicable to the remediation of petroleum hydrocarbons present in soils because hydrocarbons are biodegradable. This paper presents a review on In-situ and Ex-situ treatment processes, optimum conditions for biodegradation and effectiveness of bioremediation in clean-up of petroleum contaminated soils. Warm climates, abundant oxygen, moderate moisture content, and alkaline soil types are the favorable conditions that enhance biodegradation of Total Petroleum Hydrocarbon (TPH) present in the soil. The volume and type of contaminants are also primary factors limiting the effectiveness of bioremediation technology. Bunker C oils, a heavy fuel with complex mixtures of hydrocarbons, are recalcitrant to biodegradation and result in longer clean-up time frames. Landfarming, an onsite bioremediation technique, has been conducted on soils with moderate concentrations of hydrocarbons (~25,000mg/kg) pollutants. Substantial levels of remediation have been attained via landfarming operations within shorter time frames (4–12 week operating period) even in cold climates and remote locations. Amendments such as addition of lime to raise soil pH, bulking agents to increase aeration, and bioaugmentation significantly increase efficiency in bioremediation of petroleum contaminated soils. Enhanced bioremediation via landfarming has decreased TPH concentrations in soils by 90%, even in arctic sites with up to 4000 m^3 of soils contaminated with diesel-range organics (DRO), gasoline-range organics (GRO) and BTEX compounds.

Keywords: Bioremediation, Biodegradation, Landfarming, Total Petroleum Hydrocarbons

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11:24 am

Formation of black shales: Deep versus shallow water interpretation

David B. Olutusin

Mudstones and shales are the most common sedimentary rocks. They accumulate in a variety of environments whilst comprising the bulk of recorded earth history. Previous understanding of shale formation characterised by vertical pelagic rainout from suspension is being re-evaluated. A new theory, backed by flume experimental evidence, suggests that horizontal transports are much more important. Sedimentological experimentation of flume studies has shown that mud (shale) can form deposits at flow velocities. Black shales show distinct variability in rock properties, microfabric, sub-millimetre sedimentary textures, structures, and rock properties. Petrographic evidence including thin sections reveals mud ripples, current lamination, mud intraclasts, load structures and biotubation. These indicate the role of advective current deposit and processes in the formation of Black shales within shallow marine environments.

Black shales are organic-rich mudrock composed of silt and clay-size mineral grains. These rocks are characterized by minimum of >1% total organic carbon. Traditionally, black shales throughout the rock record were thought to have been deposited from suspension under anoxic, low-energy and quiet deep-water marine processes. These include pelagic settling, hemipelagic deposition, contourite sedimentation, turbidity current and debris flow or slides. However, recent studies have suggested that these rocks can form at any depth provided that anoxic conditions exist in water or pore fluids as well as a source of organic matter. Shale microfabric such as bedding planes, cross lamination, mud ripples, intraclasts, and biotubation coupled with flume experimental evidence supports the idea that horizontal current transport was important. Furthermore, wave enhanced sediment flow within fair and storm weather base creates the right condition for these processes. Mechanisms of rapid settling within the storm base are responsible for remobilizing shale aggregates or sediments further seaward

This new theory has led to further research focussing on two main areas. First, at what water depth were black shales formed and secondly, the factors and processes that influenced their deposition. Laboratory investigation including petrographic evidence and thin section analysis provides direct evidence of advective current transport of mud-sized material. Clay aggregates show migrating ripples deposit sediment under higher current velocities than previously believed. Observation of current-produced particle alignment suggest that current flow over the shallow shelf was the norm rather than the exception. Also, intermittent as well as continuous current flow and reworking is indicated by sedimentary features in black shales.

These evidence confirms an interpretation of the formation of black shales within shallow marine environments. Thus, it compels a rethink or re-interpretation of existing rock and stratigraphic record with regards to mudstones and black shales in particular. Finally, it refocuses a new understanding of black shales as a resource and how they could be better developed.

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11:36 am

Determining igneous structures and geomagnetic field history from induced and remnant magnetic fields

Colin Terry

Igneous rocks frequently have magnetic properties due to the presence of certain minerals, primarily iron and titanium oxides and iron sulfides. These properties include remnant, induced, and viscous remnant magnetization and effect the geomagnetic field of the Earth locally, producing measurable magnetic anomalies. Surveys record the magnetic field above geological structures. After correcting for diurnal, secular, anthropogenic effects, this data is used to create maps of these magnetic anomalies. Measurement of only the intensity of the magnetic field during the survey provides reasonable data for many interpretation purposes covered in this paper due to to the approximation that the anomalous magnetic field is equal to the change in the local geomagnetic field so long as the International Geomagnetic Reference Field (IGRF) is much greater than the intensity of the anomaly. The magnetic field anomalies can be used to determine possible igneous structures and variations in mineral composition through a variety of processing methods. By converting the data into the frequency domain, analysis of power spectrum can provide an estimated depth to magnetic sources. The practices of reduction to pole or reduction to equator provides a means of comparing anomalies that may be due to similar geology but exist at different locations on the Earth and so appear very different in their effect on the geomagnetic field. To reduce the complexity involved in modelling a magnetic field to match surveyed results, combinations of simple structures are used to approximate dykes, vertical pipes, faults, ore bodies, and so on as prisms, tabular bodies, plates, and so on. These interpretations have significant implications in gold, diamond, and hydrocarbon exploration. Remnant magnetization records information on the direction of the geomagnetic field at the time the rock cooled past its Curie temperature. While remnant magnetization is often disregarded in favour of induced magnetic effects, it provides significant data in certain geological settings and for specific purposes. In the field of paleomagnetism these remnant magnetic vectors are to provide information on tectonic plate motion, polar reversals and true polar wander, leading to a greater understanding of the geomagnetic field of the Earth and its source, the Earth's core.

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11:48 am

Resource Potential of the Barnett Shale, Fort Worth Basin, Texas

Tola Ogunniyi

The Newark east field of the Barnett Shale has the highest reserve of unconventional natural gas. This is as a result of temperature values greater than 450 °C, average total organic carbon (TOC) value of 3.5%, vitrinite reflectance of 1.3%, and thick accumulation of shale (> 107 meters) in this area. Shale gas is one of the major types of unconventional hydrocarbon, and shale gas plays can be found in fine grained sedimentary rocks that are rich in organic carbon. Porosity and permeability is usually low so it is almost impossible to produce gas commercially from shale without artificial stimulation or fracturing. Activities in shale gas have increased over the past two decades as there is need to look for alternative sources of hydrocarbons due to the finite nature of conventional hydrocarbons. 50% of natural gas produced in North America by 2020 will be from shale gas, and it is currently an important resource play in the United States for example where it accounted for more than 14% of gas produced as at the end 2004. The focus of this paper, which is also a world class example of a Shale gas play is the Barnett Shale in Fort Worth basin, Texas, United States. Geochemical data is important in determining the gas reserve of the Barnett shale, which has a continuous-type gas accumulation, with 2.7 trillion cubic feet (tcf) of booked reserves, and 26.22 tcf of total mean undiscovered shale gas resource. The Fort Worth basin deepens northwards and has structures that include fracturing, folds, faults (major and minor), as well as karst related collapse structures. Southern limit of the basin is defined by a dome (Llano uplift), and western boundary of the basin includes the Eastern shelf , Bend arch, and Concho platform. Muenster arches and the Red river mark the northern boundary of the basin, while the Ouachita structural front, is its margin to the east. The Barnett shale is middle - late Mississippian, and also serves as a source rock, seal and reservoir for unconventional natural gas resources. Besides, it is the largest field from which unconventional natural gas is produced in Texas. Lithofacies present in the Barnett Shale include black shale, phosphatic black shale, dolomite-rich black shale, lime grainstone and calcareous black shale. Further expansion of the area of production of the Barnett shale beyond the Newark east field have been very difficult to achieve and will require further geological, geochemical and engineering studies.

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12:00 noon

The Precession of the Perihelion of Mercury

Wesley Greig

The orbit of Mercury is examined with particular attention paid to the relativistic correction to Newtonian orbital dynamics. The orbit predicted by Newtonian gravity and the effect of other planets is briefly discussed and the unexplained precession of Mercury's perihelion is investigated using the Schwarzschild solution to the Einstein equations. The geodesic equation, Killing vectors, and normalization constraints are used to derive the pertinent equations of motion. These equations are then combined to obtain an expression for the gravitational potential energy. The distinction between Newtonian gravity and that predicted by general relativity is analyzed and both are compared to observed data of Mercury's orbit. Particular attention is paid to the source of discrepancy with Newtonian gravity. The magnitude of this effect on the orbits of other planets in our Solar system is briefly investigated. The importance of relativistic corrections in gravity with respect to current research in geophysics is outlined.

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12:12 pm

Stromatolites: utility, application, and challenges

Mansour Al-Hashim

Stromatolites are now well-documented and known worldwide with reported occurrences from the Archean (e.g., Transvaal Supergroup, South Africa) to Recent (e.g., Shark Bay, Western Australia). They are the most well-preserved evidence of organic activities in the Precambrian. Stromatolites are widely defined as laminated biosedimentary structures formed by trapping and binding and/or precipitation of sediment particles by means of growth and metabolic activities of non-skeletal microorganisms. The main microorganisms involved in the construction of stromatolites and their structures include photosynthetic bacteria, cyanobacteria, known as blue-green algae, and filamentous, unicellular eukaryotic green algae. The morphology of stromatolites is however the product of interaction between various physical, chemical, and biological (microbial) factors that exist in the environment during their formation. This complex relationship between many different factors and the formation of stromatolites is the main source of their importance. Stromatolites are particularly useful in sedimentology, stratigraphy, paleontology, and paleoecology. They have been utilized in studying ancient depositional environments, in estimating sedimentation rates, in correlating and dating stromatolitic formations, and in regional mapping. They were also used in solving problems related to paleocurrent directions, paleolatitudes, and ancient shorelines and water depths. Understanding the microbiology and ecosystem of modern stromatolite-building biota and the processes by which modern stromatolites are being formed is critical for any sophisticated and plausible interpretation of ancient stromatolite forms. A thorough examination and description of old stromatolites is by no means less important in understanding the recent ones.

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Microbial interactions with physical sediment dynamics, and their significance for the interpretation of earth's biological history. (2008). *Geobiology, 6*(1), 93.

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1:24 pm

Microfossils and the Origins of Life on Earth

Roderick Tom-Ying

Much of our understanding of life on Earth is centered on the well-studied Phanerozoic history of life where the evolution of species is well preserved in the rock strata. Unlike the Phanerozoic Eon, the basis of study for life during the Precambrian is centered on the prokaryotic microbes. Due to the nature of microbes and the poorly preserved rock record, the discussion of Precambrian fossils, as merits in inferring the origins of life are highly debated. The Apex chert formation, almost 3.5 Gya in age, found in Western Australia is a highly debated rock formation as it contains microfossils that appear biotic in origins. Held within the Precambrian chert formation is the possibility of Earth's earliest biotic microfossils. The basis of many early life hypotheses hinders on the fact that microfossils found within the rock formation appear organic in origin. Here we show that by re-examining the carbonaceous composition of the microbial filaments of said microfossils, the filament diameter, and by using Ramen Spectroscopy we infer an abiotic origin. As the basis of the Early Life Hypothesis centers upon the fact that the fossils found within the Apex chert at 3.5 Gya, by re-examining the evidence we conclude that the fossils within the Apex Chert are pseudo fossils. We anticipate our results to be a starting point for a comprehensive re-examination of the Early Life Hypothesis.

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Early to Middle Ordovician Climate, Paleogeography, and Environments: Their Affects on Faunal Radiation

Kathryn Lapenskie

The Early to Middle Ordovician Earth differed greatly from the present-day planet in terms of geography, climate, environments, and marine ecosystem composition and structure. The Early to Middle Ordovician climate is characterized by greenhouse conditions, with atmospheric CO_2 concentrations up to ten times higher than modern values. High global temperatures limited or prevented the development of continental ice sheets, allowing for sea levels to attain their Phanerozoic maximum by the end of the Ordovician. The maximum continental dispersal of the last 540 Ma was achieved as four large continental landmasses, as well as microcontinents and island arcs, were widely distributed throughout the southern hemisphere. The northern hemisphere was unoccupied by continents and covered by the vast Panthalassic Ocean.

Extensive epicontinental seas developed in the southern hemisphere due to globally high sea levels. Wide temperate and tropical marine belts developed as a result of a greenhouse climate. Sluggish ocean circulation limited the upwelling of deeper, nutrient rich waters, causing superoligotrophic conditions. Hardgrounds and flat sea beds became common throughout the shallow cratonic seas. Island arcs and ocean terranes provided fauna platforms on which to migrate and radiate on.

The Great Ordovician Biodiversification Event was a significant faunal radiation, occurring in a 25 million year interval during the Early to Middle Ordovician. Several climatic, environmental, and tectonic factors led to the development of this event. Geographic isolation of organisms, due to fragmented continents and intense tectonic activity, drove speciation and diversity. The extensive tropical, shallow epicontinental seas created by the greenhouse conditions and high sea levels provided habitats for organisms to thrive in. Increased primary productivity in cratonic seas enabled a subsequent diversity of primary producers.

Organisms with mineralized skeletons became highly diversified during this radiation, including brachiopods, bryozoans, cephalopods, conodonts, solitary and colonial corals, echinoderms, graptolites, ostracodes, sponges, and trilobites. Reef composition changed from microbially- to metazoan-dominated framework builders. New niches were exploited as organisms occupied different tiers above and below the sediment-water interface. Planktonic animals expanded their environments to inhabit greater ranges of the water column. The poorly organized ecosystems of the Cambrian Period, dominated by epifanual animals, were replaced by complex, predictable food webs. The new families, genera, and species arising out of the Great Ordovician Biodiversification Event compose the Paleozoic Evolutionary Fauna, which dominated marine communities until the end of the Permian Period.

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Recognition of tsunami deposits within the sedimentary record: Attempts at establishing a tsunami facies

Beth Hooper

Tsunami deposit identification within the sedimentary record is difficult due to characteristics such as preservation potential, grain size, and depositional environment, causing the appearance of the deposit to vary. To date, tsunami deposits have yet to be identified based on sedimentary criteria alone, requiring dating of sediments immediately overlying each deposit followed by a comparison to a record of historical tsunami occurrence. The establishment of a sedimentary facies unique to tsunamis has implications for further deposit identification and, by extension, risk assessment.

A review of scientific research on tsunami deposits from different parts of the world, including Japan, Australia, and Portugal, have provided a baseline of common sedimentary characteristics, as observed through trenching and coring techniques. Deposits are commonly divided into four sub-units, each of which is interpreted to correspond to a different phase of the tsunami; the initial, smaller waves of the tsunami depositing the lowest most unit, followed by the large, powerful waves, the waning energy waves, and finally the post-tsunami fall-out. Sedimentary characteristics of the deposits have included landward thinning and fining, rip-up clasts, cross-bedding, grading, and boulders, to name a few. This paper provides an overview of features common to tsunami deposits as well as limitations associated with their discovery and interpretation.

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2:00 pm

A Comparison of two Projects for the Prevention of High Water in the City of Venice, Italy, as a Result of Land Subsidence and Climate-Induced Sea Level Rise

Filippo Resente

The frequency and intensity of flooding in the city of Venice, Italy, has increased over the past 50 years. This phenomenon is governed by a combination of geological, historical and climatological factors. This review will aim to summarize the geomorphological evolution of the Venetian Lagoon and of the land subsidence phenomenon, meanwhile providing a background of the historical evolution of the area. This will include the main anthropogenic causes of flooding in Venice and the recent attempts and future options to save Venice from rising water levels. In particular, we will examine the two most discussed projects: the Experimental Electromechanical Module (MoSE project), and the Anthropogenic Uplift of Venice City . The MoSE project was approved by the Italian government in 2001 and is currently under construction. It consists of movable barriers installed in correspondence with the three lagoonal inlets and is designed to block seawater inflow into the lagoonal basin during exceptional tidal events that cause flooding in Venice. With the current sea level, the activation of the movable barriers is expected to occur with a frequency of 2-3 times per year but may increase as a result of climate-induced sea level rise. This will have a negative impact on harbour activities in Venice as maritime traffic will be limited at the inlets. As a result, MoSE project might become obsolete in less than 100 years. A complementary project has been proposed: the Anthropogenic Uplift of Venice. It consists of 12 vertical wells strategically located within the lagoon, that inject seawater into the 600-800 deep aquifer. The numerical model described here, predicts an uplift of between 11 and 40 cm over a 10 year period. Preliminary results shows that the anthropogenic Uplift of Venice might be a promising complementary action to MoSE barriers as it has the potential to reduce the frequency of the closure of the inlets by prolonging the operational life of MoSE.

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2:12 pm

Effects of Climate-Induced Temperature and Water Table Changes on Carbon-Dynamics of Northern Peatlands

Tara Despault

Peatlands account for only 3% of the Earth's land area; however they are an important net carbon sink, with northern peatlands storing up to 30% of the world's carbon stocks. Climate change is expected to have a significant impact on the structure and physicochemical characteristics of peatlands, especially those at high latitudes. Of the projected consequences, warmer temperatures and water table drawdown are of particular concern, each having direct and indirect effects on the carbon-dynamics of peat soils. This review will aim to provide a general summary of how changing environmental conditions will impact various aspects of the carbon cycle in northern peatlands, specifically soil and gaseous carbon. Increased temperature and lower water table levels have been found to enhance decomposition rates of organic matter in soils, which would effectively increase carbon dioxide emissions to the atmosphere. Warmer temperatures will provide favourable temperatures for methanogenesis, however a lowering of the water table below 10-20 cm and change in plant community structure could decrease the amount of methane that is emitted to the atmosphere. The drivers of dissolved organic carbon concentrations in peatlands are not yet known, which creates uncertainty in the estimation of how dissolved organic carbon responds to climatic disruptions. Drought has been found to decrease dissolved organic carbon concentrations owing to increased mineralization rates, but greater temperatures have been noted to have both positive and negative effects on concentrations. This overview suggests that climate-induced warming and drying of northern peatlands will increase carbon dioxide and decrease methane effluxes from soils, however no clear consensus for soil carbon components has been established.

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Millennial Climate Cycles in the Holocene

W. James Goacher

Future climate projections have been constrained to what can be concluded of the mechanisms that drove climate change in the past. As climate change becomes a more global public concern, the need for a complete understanding of natural climate cycles is critical before the recent anthropogenic impact can be interpreted relative to the natural variability.

Holocene climate, the most recent interglacial period, was thought to be relatively stable until paleo records uncovered a common millennial periodicity. Glacial and interglacial cycles driven by Milankovitch orbital forcing operate on a scale of > 20,000 years. However, these cycles can be punctuated by shorter cycles of lower amplitude such as 11-year Schwabe cycles, 85-year Gleissburg cycles, and 207-year deVries cycles. Recently, a new millennial climate cycle of ~1400 years has been evidenced by various paleo records and suggest a much larger global impact mechanism.

Carbon-14 and Beryllium-10, both cosmogenically created proxies for total solar irradiance (TSI), have been correlated to these millennial climate cycles. This evidence suggests that solar forcing may contribute to a new time scale of climate variability in the natural environment. Based on isotopes, pollen, and *foraminifera* paleo data, it has been hypothesized that solar forcing influences the atmosphere enough to change the sea surface temperature, the North Atlantic Oscillation (NAO), and even the thermohaline circulation of the ocean. The resulting change in North Atlantic Deep Water (NADW) formation amplifies this solar forcing to a global scale and may have implications for our current climate-warming event.

Other mechanisms have been presented in the literature including volcanism and glacial influence. Thus, more research will need to be done in order to conclusively determine the main driving force of this millennial oscillation. Linking these mechanisms of climate change is crucial to understanding Earth's past climate regimes and making predictions for Earth's future climate.

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Strength of the Continental Lithosphere

Mengmeng Qu

The strength of the continental lithosphere, or maximum stress it can support before failing, is crucial in geodynamics. Its spatial and temporal variations can help us understand the Earth's deformation processes including rifting, mountain building, sedimentary basin development, seismicity and volcanism.

In the 1970s, Goetze and Evans firstly introduced the yield stress envelope (YSE), a vertical profile predicting the maximum differential stress supported by rock as a function of depth for the oceanic lithosphere. This concept works well for the oceanic lithosphere, because it can explain the response of observed age and temperature dependence of plate to surface and subsurface loads. But when it comes to the continental lithosphere, problems appear. Compared with oceanic lithosphere, continental lithosphere is in a much more complicated context. It has a thicker crust and a longer deformation history, and bears the modification by surficial process (e.g., erosion, sedimentation and orogenesis). In the 1980s, based on the study of the distribution of focal depths for earthquakes, Chen and Molnar stated the classical view on the strength of the continental lithosphere: the continental lithosphere generally consisted of a weak lower crust sandwiched between a relatively strong upper crust and uppermost mantle. This is known as "jelly sandwich".

However, at the beginning of the 21st century, after the reassessment of earthquake depth distributions and gravity anomalies, Jackson and Maggi found that there was little support in earthquake focal depth distributions, for the uppermost mantle was significantly stronger than the lower crust in continental regions. Therefore they proposed an opposite view, "crème brulée", suggesting that the strength of the continental lithosphere resided in the crust, and that the upper mantle beneath the continents was relatively weak. To analyze which idea is more applicable, in accordance with them, Burov used dynamic numerical models to test the stability and structural styles. The results turned out to be compatible with the view that the lithospheric mantle was strong ("jelly sandwich") and in this way, the continental lithosphere could support geological loads and stress for long periods of time. Therefore, they concluded that "jelly sandwich" was more widely applicable.

In the paper, I review the two opinions about the strength of the continental lithosphere and focus on recent researches: 1) Jackson and Maggi's study on the focal depth distribution of earthquakes and the association of gravity anomalies with topography; 2) Burov's dynamic numerical models. Then I analyze problems in these researches and general difficulties in studies of the strength of the continental lithosphere.

In the end, I give my own understanding of the strength of the continental lithosphere and perspectives on future studies.

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2:48 pm

Shale gas in Canada: geological controls and current challenges

Weiyin Chen

Abstract: Natural gas accounts for a significant part of the energy consumption around the world. With the increasing concerns about unconventional natural gas, the exploration and exploitation of shale gas has developed dramatically in recent years, and it result in the increase of natural gas reserves. The term “Shale Gas” refers to unconventional, continuous-type, self-sourced resources contained in fine grained (ranging from clay to very fine sandstone), organic-rich, low permeability reservoirs in which thermogenic or biogenic methane is stored as free gas in the matrix or fracture porosity, or as adsorbed/dissolved gas on the organics and/or clays. These are self-enclosed petroleum systems, characterized by inefficient “dysfunctional” expulsion and migration, where source, reservoir and trap are all present in the same thick shaly succession. The most prospective shale gas targets will be thick, widespread, gas-saturated, fine grained, organicrich units. There are three main geological controls for shale gas plays: tectono-stratigraphic position, organic matter content and reservoir characteristics. Thickness and distribution area is the key conditions which ensure there is enough storage space and organic matter. There is positive correlation between the organic matter content and the methane capacity of shale. The features of pore and fracture determine it whether we can get access to the economic flow and how we design the project for hydraulic fracturing. Besides, challenges for the development of shale gas in Canada are analyzed in the end. The intrinsic characteristics of the shale gas and the fundamental controls on its productivity need to be well understood. Currently there are few production wells in Canada with a history of well performance that can be used to extrapolate recoverable potential. The assessment methodology for continuous resource must be flexible enough to adapt to situations ranging from little or no well data to thousands of production wells. Modern geological information, beginning with maps, is needed for evaluation of shale gas targets.

Keywords: Shale gas; Geological controls; Canada; Challenges

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3:12 pm

Groundwater remediation using zero-valent iron as a reactive medium in permeable reactive barriers

Alana Crump

Conventional methods of groundwater remediation involve pumping water to the surface where subsequent treatment occurs, followed by the release of this treated water back into an aquifer. However, these pump-and-treat systems are energy and maintenance intensive, invoking the need to replace traditional technologies. Permeable reactive barriers (PRBs) have recently emerged as a viable method for passive remediation of contaminated groundwater. These barriers are installed in the path of a contaminated groundwater plume and contain reactive materials that promote various geochemical reactions. PRBs therefore transform contaminants into innocuous components as groundwater flows through a subsurface diaphragm under the natural hydraulic gradient. Adsorption or redox reactions followed by the precipitation of sparingly-soluble compounds are examples of processes occurring in PRBs, however the ability to predict long-term performance of PRBs in different hydrogeochemical environments is difficult.

The use of Zero-Valent Iron as a reactive medium is of particular interest for the treatment of numerous contaminants. This material is the most-widely used medium for permeable reactive barriers, and laboratory and field experiments have proven its effectiveness. Meanwhile, several experiments have demonstrated that the formation of secondary precipitates often reduces the permeability of PRBs over time. Although current studies advocate the use of this method as a replacement for groundwater remediation, additional research must be conducted regarding the long-term effects of these precipitates on porosity and hydraulic conductivity. This review therefore outlines PRB technology, provides a list of contaminants that are treatable using Zero-Valent Iron, and summarizes problematic aspects of this method that have been determined in laboratory and field research.

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Mining salt, brine and clay: A review of lithium and boron evaporite deposits

Sean Fulcher

Hydrogen fuel cells and battery powered electric vehicles are at the cusp of focus for electrical power storage as their need for portable power and energy is directly relative to their success. Elements such as lithium and now boron have been targeted as candidates to solving chemical-electrical storage problems. Lithium and boron are extracted from continental nonmarine evaporite deposits that comprise 82.7% and 90% of the world supply respectively (Dundee Capital Markets, 2009) (Smith & Medrano, 1996) and are extracted principally as salts, brines and clays (Warren, 1999).

The following paper is a review of lithium and boron evaporite deposits focusing on their origins, hydrogeochemical controls, extraction and economics. Deposits are segregated based on lithium-boron bearing mineralogy or brine chemistry. Depositional facies, stratigraphy and diagenesis are overviewed and illustrate a complex hydrogeological system dependent on water-rock interactions.

Economic parameters of deposit types efficiency, sustainability and economic potential are defined. Findings converge that lithium brines are the most economical source of lithium carbonate still but offer significant setbacks to product to market timing because of solar dependence for concentrating brines and the variability of brine in aquifers. In contrast, boron production is strongly concentrated in Turkey and the U.S.A with 72% of total reserves located in Turkey (Kar, et al. 2006) and offers a stable supply platform. Conversely, economic potentials of evaporite deposits are solely dependent on demand and emerging technologies. Boron is viewed as having a higher economic potential because of emerging uses of borohydrides in hydrogen fuel cells.

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Self-organized criticality: What can it tell us about natural hazards?

Xiaoming Zhang

Self-organized criticality is a phenomenon that describes a system evolves to a critical state spontaneously rather than by external fine tuning of a parameter as in phase transition. A system described by self-organized criticality exhibits power-law behaviour and fractal size distribution of events. The concept of self-organized criticality evolved from the study of three major types of models: the sand-pile model, describing the evolution of a sandpile by consistently adding sands; the forest fire model, which involves the dynamics of burning trees and the avalanches in the system are forest fires; and the slider-block model, which is a simple analogue for the behaviour of faults in the Earth's crust through blocks motion driven by the friction force of a plate. Self-organized criticality has been successful in describing complexity, together with chaos and fractals. It has been proven to be a new approach to study a wide range of complex systems from large scale natural phenomena to human social behaviour, e.g. landslides, earthquakes, forest fires, brain activity, stock markets, epidemics.

Some natural hazards such as landslides, forest fires and earthquakes are characterized by unpredictable events, or avalanches, as well as a power-law scaling of frequency-size distribution. For example, the Gutenberg-Richter law, which describes the size distribution of earthquakes, exhibits characteristics of self-organized criticality. Simple self-organized criticality models have been proven to display strong descriptive power and can be directly applied to natural systems. The aim of this paper is to introduce the framework of self-organized criticality and review the applications of models to natural hazards. The sand-pile models have been applied to landslides and rockfalls, the forest fire models to forest fires and wild fires, the slider-block models to earthquakes. In addition, potential self-organized criticality models for volcanic eruption are discussed. The model behaviour yields to a good analogue of the actual observations, the estimates of the size and frequency of possible events can be drawn. Moreover, acquiring more insight into the mechanism of natural hazards through investigating the model behaviour could further foster constructing hazard and risk assessment systems.

Self-organized criticality is still at an early stage of development and not a well-defined concept. It is controversial in the sense that the process of self-organizing into the critical state and the mathematical proof of the power-law behaviour is not quite clear. Nonetheless, self-organized criticality serves as an approach to an in-depth understanding of the dynamics of dissipative non-equilibrium systems. Questions remain as to whether or not it is really a 'universal' behaviour and truly captures the essence of the phenomenon.

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Basin Controls on the occurrence of Reservoir Intervals in the Cardium Formation, AB

Tararat Lerkwieng

Mudstone and sandstone are the major rocks that can be found in Cardium formation where outcrops the Rockies foothills and lies beneath the Alberta plain. Conglomerate fractions could also be found in this formation not a lot but important. Sediments were accumulated in the area of muddy and sandy marine environment. The process of autocyclic and allocyclic controlled depositional basin. Cardium sediments are contained by a large bow- shaped basin, which follows an elongate compound arc that trends northwest.

The tectonic system as the Tintina-Northern Rocky Mountain Trench (TT-NRMT) fault system transformed from right-lateral strike- slip to compressional deformation basement subsidence increased in the southern Canadian Rockies. As orogenesis occurred large amounts of sediment were delivered to the subsiding basin contributing to overall subsidence. High-frequency fluctuations in sea level due to eustatic and tectonic controls resulted in the complex depositional patterns of the Cardium formation. .

The Cardium formation is a prolific hydrocarbon deposit producing both conventional and unconventional resources. Basin controls on reservoir units are mainly tectonic and also eustatic. Orogenesis caused subsidence in the Alberta Basin creating a large sediment source and accommodation space to deposit ‘the prograding clastic wedge of the Cardium formation. Relative changes in sea level caused an erosional unconformity and back stepping, which combined with gravel input and wave reworking created some of the best reservoirs in the Cardium formation. Conglomerate and high quality sand reservoirs were originally conventional targets. Presently low permeability ‘fringe’ or ‘halo’ deposits around high quality reservoirs are popular unconventional horizontal fracturing targets.

Keywords: basin; subsidence; eustatic; prograding clastic; conventional; unconventional

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4:00 pm

Seismic risk in Canada

Yelena Kropivnitskaya

The seismic hazard exists almost anywhere in the world, and Canada is no exception. Every day there are about 3-4 earthquakes in this country, and in spite of the fact that most of them can only be detected by sensitive equipment, a few times a year, Canadians really feel the movement of the earth. The urgency of this issue highlights by the fact that a strong earthquake near large cities in Canada can produce damage in the billions of dollars and lead to the deaths of thousands of people. Most seismically hazardous territory of Canada is Western Canada, particularly British Columbia. Seismic activity in this region caused earthquakes with magnitudes greater than 8 Richter. Also in eastern Canada there is a risk of seismic hazard. The evidence is devastating earthquakes up to magnitude 7 Richter, occurred near the St. Lawrence and Ottawa rivers and earthquakes near North Bay, Ontario, in January 2000 and the earthquake in Georgian Bay in October 2005. In central Canada there is no significant risk of earthquakes. That is why in this paper will be considered a historical aspect of seismic and seismic risk in Western and Eastern Canada.

The analysis of seismic risk is determined as the consequences and the likelihood of hazardous events that can happen in that period of time, which is one of the most important tasks of management and is used to analyze the economic, social and environmental consequences of hazardous events. In the context of this paper will discuss the main theoretical approaches to the analysis and evaluation of seismic risk, and methods to reduce it. Determination of seismic risk in Canada plays an important role in the upcoming events, which can greatly help in the assessment of risk and response planning, mitigate losses and tragedies associated with these extremes, and reduce the effects of seismic hazard on the Canadian citizens and infrastructure of Canadian cities.

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4:12 pm

Uses and Challenges in Real-Time seismological data applications

Behzad Hassani

Real-time seismological data applications refer to the applications in which seismic data are received and analyzed quickly after a significant seismic event, so that the results can be effectively used for post-earthquake emergency response and early warning. In general, real-time applications are based on two distinct procedures. In first one, the rapid (3-5 minutes) generation of maps of instrumental ground-motion (acceleration, velocity, and spectral response) and shaking intensity accomplished thorough near real-time seismographic data acquisition combined with developed relationships between recorded ground-motion parameters and expected shaking intensity values. These automatic maps which are triggered by any significant earthquake can provide a rapid depiction of the extent of potentially damaging area following an earthquake and can be used for emergency response, loss estimation and for public information through the media. As the technology of seismic instrumentation, telemetry, computers, and data storage facility advances, the real-time seismology for rapid post-earthquake notification is essentially established.

The second procedure which is called Earthquake Early Warning (EEW) is based on the idea that seismic waves radiate at a lower speed than electromagnetic waves that are used to transmit possible warnings in case of strong events. This leading time can be implemented to reduce likely damages that might be caused by the later arriving seismic waves. Research for EEW is currently in progress and two methods are widely used: (1) regional warning and (2) on-site warning methods. In regional warning method, the traditional seismological techniques are used to locate an earthquake, determine the magnitude and estimate the ground motion at other sites. In on-site warning method, the beginning of the ground motion (P wave) observed at a site is used to predict the following ground motion (S wave) at the same site and no attempt is necessarily made to locate an earthquake and estimate the magnitude. The first approach is more reliable, but it takes a longer time and cannot be used for the sites at short epicentral distances. However, the second approach is less accurate, but it is very fast and can provide useful early warning to sites even at very short distances where an early warning is most vital. To benefit from the advantages of both methods some integrated approaches have been proposed to not only use the accuracy of the first approach but also benefit from the fast responses of the second approach. The uses of EEW can be considered both at personal and institutional levels. For instance, Personal protective measures can be undertaken at home and in the workplace include getting under desks and moving away from dangerous chemicals and machinery. At institutional level, protective measures can be exploited at mass-transportation systems that can use a few seconds to slow and stop trains, terminate airplane landings, and prevent additional cars from entering the freeway.

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Detachment faulting and it's implications for the mineralization of Oceanic Core Complexes

Jon Hey

Scientific interest in oceanic core complexes (OCC) has greatly increased since the initial mapping expedition to the Atlantis Massif is 1996. Ongoing research has focused on mantle structure, marine magnetic anomalies, OCC fromation formation and their relation to detachment faults. OCCs form on the inside corner of ridge transform-fault intersections along slow spreading to ultra-slow spreading ridges. Current models support long-lived, large-scale detachment faults, creating axial asymmetry. Reduced magma supply and the exposure of lower crustal and mantle rocks suggest extension involving predominantly tectonic instead of magmatic processes. The hanging wall of these faults are typically metamorphosed ultramafic schists, with a serpentinized peridotite in the footwall, intruded by discrete gabbroic bodies. The fault comprises a network of smaller anastomosing fault zones, generally dipping at ≤20°. The fault gouge is typically 1 – >200 m thick. Recent studies have shown that hydrothermal mineralization has been occurring at temperatures of 300-400°C up to 12 km off-axis along the Mid-Atlantic Ridge. New oxygen and strontium isotopic evidence has shown that active oceanic detachment faults can focus large volumes of hydrothermal fluids, and are the primary conduits for these fluids and slow spreading ridges. Geophysical studies of the Trans-Atlantic Geotraverse (TAG) have shown that the detachment fault dips at roughly 20° towards the ridge axis until a depth of 1 km, at which point it plunges at 70° to a depth of >7 km. There is also no geophysical evidence for any crustal melt reservoirs at shallower depths to provide heat to the fluids. The evolution of detachment fault mineralization can be broken down into three stages: 1) early, intense hydrothermal circulation, driven by hot gabbroic intrusions into serpentinized ultramafic footwall rocks. TAG-type vents occur here during final discharge with a preference from Fe-Cu-Zn-Si mineralization in basalt; 2) fluid flow through the mature detachment has fluids interacting with both gabbroic intrusions and serpentinized peridotite, discharging through ultramafic rich footwall rocks at ~370°C in Rainbow-type vents, showing high temperature Cu-Zn-Fe-Co-Au-(Ni) sulfide mineralization in ultramafics; and 3) low temperature circulation in cooled peridotites distal to the ridge axis generates low-temperature Si-(Zn-Cu) and Ca-Mg deposits in Lost City-type venting. The Cu-Zn-Co-Au deposits are more common in OCCs than in ophiolites, suggesting that ultramafic hosted volcanogenic massive sulfide deposits on slow spreading ridges fail to accrete during obduction and are thus a type of mineralization specific to the marine environment. Based on the extensional nature of OCC formation, it may be possible to find obducted complexes in failed rift zones accreted to continents.

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Models and Timing of Core Formation

Sean P. Funk

Over the past one hundred years, important discovers about the core have come from seismology, magnetics, and geodesy. However, the exact mechanisms involved in the formation of the core are still a mystery. Important constraints on core formation can be placed from Hf-W isotopes [1] and looking at siderophile (metal-loving) elements in the mantle [2]. Hostetler and Drake[3] proposed that a "magma ocean", a consequence of accretion, formed on Earth. The "homogeneous magma ocean hypothesis" envisions that shock-induced melting caused metal and silicate to segregate, with the metal sinking toward the center of the proto-Earth.

Despite the initial success of the model in predicting the large-scale general distribution of metals and silicates, it fails to explain certain aspects of trace element geochemistry and isotope systematics. For example, the "excess siderophile element anomaly" (ESEA) in particular has been very troublesome to explain[4]. The ESEA demonstrates that the mantle, although depleted in siderophile elements relative to chondrites, is greater than predicted with known high-pressure equilibrium metal-silicate partitioning coefficients[5].

In this review, I will discuss three alternative hypotheses on core formation, and evaluate and critique each model with respect to the chemistry and physics involved. The first is core-core disequilibrium mixing, whereby the cores of differentiated bodies merge together quickly[6]. Here, the physics of emulsification become important to evaluate. Descending metal droplets are subject to Rayleigh-Taylor and Kelvin-Helmholtz instabilities, which act to tear the droplets apart. Only the largest descending cores may survive hybridization. Another is "inefficient core formation", where metallic material gets trapped within the mantle, later to be re-oxidized and redistributed[7]. The mode of metal transport, percolation versus dyking or diapirism, become important. Based on the dihedral angle (θ) of Earth materials at high-pressure, it seems unlikely that this is a viable model. The last is known as the heterogeneous accretion (or late veneer) model, where the composition of the accreting material changes with time[8]. During the late stages of core formation, a "late veneer" of material added siderophile elements into the mantle[8]. At present, this is the most widely accepted hypothesis that best explains core formation.

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Monday November 26, 9:30 am in BGS 1053

Dominant gliding versus pure spreading in passive margins: the effect of differential sedimentation on initiating salt tectonics

Sarah N. Sweeney

Dominant gliding and pure spreading are both gravity driven salt tectonics models, but they form in two different ways. Dominant gliding is primarily gravity driven via marginal tilt with a minor implication for the impact of sedimentation. Conversely, pure spreading is driven only by differential sediment loading in a horizontal environment. When discussing the application of the dominant glide model as opposed to the pure spreading model in passive margins, determining the effect of differential sediment loading on initiating salt tectonics is a major point of contention.

In "Salt tectonics at passive margins: Geology versus models" by Brun and Fort, 2011, the application of numerical and experimental models concludes that in order for differential sedimentary loading to initiate salt tectonics, abnormally thick and/or dense sediments, in conjunction with anomalously low sediment friction would be required. According to Brun and Fort, 2011, dominant gliding is more efficient and significantly easier to initiate than pure spreading. These findings, specifically 1) the equations used, 2) the laboratory experiments, and 3) the geological analogies, were hotly contested by Rowan in a discussion article published in 2012. Rowan advocated that pure spreading has a much larger impact than implied by Brun and Fort, 2011. However, the majority of the concerns by Rowan, 2012, are based on 1) numerical models that don't account for the same variables, 2) laboratory experiments done by other authors working with Rowan, and 3) an overall misunderstanding and misrepresentation of what was published by Brun and Fort, 2011. Despite the opposing views, both authors agree that the effectiveness of models in a geologic setting cannot be guaranteed and that both dominant gliding and pure spreading are normally occurring processes.

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Weathering-induced metal-enrichment processes, the aluminium and nickel cases

Martin Arce

This paper reviews the processes responsible for the enrichment of metals through intense weathering of rocks. It provides a basis for understanding the general weathering phenomena and its relationship with tectonic and climate. It also describes the main characteristics of the two major weathering-related deposits in terms of mine production, aluminium and nickel laterites, as well as their basic concentration mechanisms. Weathering results of the interaction between the hydrosphere, biosphere and lithosphere under determined tectonic, climatic and topographic conditions, where some elements of primary minerals are lixiviated and secondary minerals are produced as residua. Laterite is the most generally accepted denomination for the product of intense weathering in humid, cold to warm climates and sub-artic to tropical regions during sufficient time under conditions of tectonic stability. The final product of weathering is a mineral assemblage of the least soluble minerals and the most resistant primary minerals. The evolution of laterites on parent rocks with pre-concentration of certain metals cause rock destruction and reorganisation of these elements in new supergene associations which either stay within the profile or migrate in solution.

Bauxite is the only source used for production of alumina on industrial scale, world production during 2011 reached 211000 thousand metric dry tons. Bauxite is a lateritic rock characterized by the extreme enrichment of aluminum hydroxide minerals, such as gibbsite, boehmite and diaspore, together with iron oxides, kaolinite and less anatase. Laterites and bauxites are generated in tropical environments by intense weathering with the consequent enrichment in iron (laterites) and in alumina (bauxites) to ore grades. If compared to laterites, bauxites are generated by stronger leaching. Dissolved silica concentration is lowered by the intense leaching, enhancing formation of gibbsite instead of kaolinite. A classification based on the tectonic frame includes bauxites in uplift areas, in subsiding platforms, and in carbonate platforms.

Nickeliferous laterites currently represent the major nickel reserves, approximately 48,000,000 metric tons of nickel content. Even though 60% of world nickel reserves are composed by lateritic nickel, only 40% of world nickel production is generated from this source. It is due to the difficulties and the higher energy consume in metallurgical processing of nickel oxides compared to nickel sulfides. Progressive and intensive weathering of ultramafic rocks generally under tropical conditions (it also occurs in wet cold regions at much lower rates) generates economic concentrations of nickel, platinum group elements and chromium. Cobalt and copper are usual by-products but also can constitute deposits by themselves. Based on its mineralogy, lateritic nickel deposits are classified in hydrous silicate deposits, clay silicate deposits and oxide deposits. The importance of weathering-forming deposits processes and the convenience and/or need of mining them are highlighted and demonstrated in this contribution through the examples of the two major commodities mined from them.

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Geophysical Techniques for shallow Subsurface Ground Penetrating Radar (GPR), Multi-Channel Analysis of Shear Waves (MASW) Seismic Refraction and Reflection

Wajahat Ali

Shallow subsurface is an important geological zone which is directly related to human life in terms of water supply, agriculture and ecosystems. Several geophysical techniques are available for the investigation and characterization of shallow subsurface. Most commonly used are the electrical methods, seismic refraction and reflection methods, multichannel analysis of surface waves, gravity, magnetic, electromagnetic induction and ground penetrating radar. Each of the techniques is based on a specific physical law. An attempt has been made in this paper to describe the seismic and ground penetrating radar techniques with their advantages and limitations.

Seismic reflection and refraction methods involves the study of body waves (P and S waves) travelling through the earth interior, reflecting and refracting on the interfaces and discontinuities having different acoustic impedances. Multichannel analysis of surface waves involves the study of surface waves travelling along the air and earth interface suffering dispersion, whereas ground penetrating radar involves the analysis of reflected electromagnetic signals from the objects having different dielectric constants. Reflection method describes the subsurface stratigraphy and discontinuities (such as faults and erosional surfaces) efficiently. Refraction method is mostly to estimate the depth to the bedrock. Analysis of dispersive surface waves identifies the zones having voids, weathered and fractured bedrock. Ground penetrating radar uses the principle of reflection of electromagnetic energy which identifies subsurface utilities, fractures, void and archeological sites.

Each technique has its own limitations and drawbacks. The depth range of ground penetrating radar depends upon the electrical conductivity of the subsurface. In ground having high salt content, the depth of penetration may not reach few centimeters where as in ice it may reach several hundred meters. On the other hand a dipping layer in shallow subsurface significantly affects the shear wave inversion results apart from the maximum resolvable wavelength of the fundamental mode with respect to the spread length. Reflection and refraction methods will depend upon the spread length, offsets and kind and frequency contents of the source used.

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Database for flooding susceptibility, hazard, and vulnerability assessment

Hadis Samadi Alinia

Disasters are natural and human-caused events that have an adverse impact on a community, region, or nation. Events associated with a disaster can overwhelm response resources and have damaging economic, social, or environmental impacts. Floods are some of the most common and costly natural disasters around the world. These events occur in most countries, and cause the most deaths and it is expected that the extent of flooding increase under the influence of climate change and economic development.

There is a need to clarify the nature and impacts of the flood hazards in a hazard analysis process. The assumption is that negative effects of disasters can be reduced through preparation. Much effort has gone into preparing people of disaster prone areas to withstand the effects of disasters. A number of approaches have been applied for disaster preparedness. They focused on prior information regarding impending disasters, frequency and severity of disasters, causes, effects of disasters and their reduction or mitigation, perception of risk, removing people from disaster prone areas, disaster preparedness, coping and adjustment, post-disaster rebuilding and return to normalcy.

Among these, Geo-information and remote sensing are proper tools to enhance functional strategies for increasing awareness on natural hazard prevention and for supporting research and operational activities devoted to disaster reduction. GIS along with remote sensing has become the key tool to delineate of flood prone areas and development of flood hazard maps indicating the risk areas likely to be inundated by significant flooding along with the damageable objects maps for the flood susceptible areas. Producing rescue and flood vulnerability map and updating it using satellite images would help for evacuation and dispatching resources and aid scared people to the safe regions in a short time.

As producing susceptibility, hazard, and vulnerability maps is composed of various criteria involved in the flood disaster, reliable, up-to-date, and accurate geospatial and non-spatial data is significant. With respect to the environmental factors used in Flooding hazard assessment, there is a tendency to utilize those data that are easily obtainable from Digital Elevation Models and satellite imagery, whereas less emphasis is on those that require detailed field investigations.

This paper is the review on the types of spatial and non-spatial data needed in this hazard case and the approaches for obtaining them and also mapping the infected zones. This paper is a review in collecting spatial and non-spatial information on environmental factors with a focus on Digital Elevation Models, geology and soils, geomorphology, land use and elements at risk.

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