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DEEPWATER HYDROCARBON EXPLORATION

Abstract

Mass Transport Deposit (MTDs) processes are important in slope deposits of both active and passive margins basin floors(petroleum reservoirs, sand injectites).In these settings, significant slope sediment instability and failure mobility result from high rates of deposition, gas-charged sediment, growth faults, salt tectonics, diapirism etc. Mass Transport Complexes (MTCs) contain sufficient porous and permeable sediment are significant constituents of the fill of the basins to constitute hydrocarbon reservoirs. These MTCs are composite stratigraphic bodies consisting of resedimented materials associated with slumps, slides, debris flows, turbidites, and hemipelagites. Mass-transport deposits are sedimentary, stratigraphic successions that remobilize after initial deposition but prior to substantial lithification and transported down slope by gravitational processes. Mud–prone mass-transport deposits are from far the most common type of mass-transport deposits in deep-water settings ninety percent.sand-prone mass-transport deposits can contain high-quality reservoir sands, porosity can be in excess of thirty percent, and permeabilities on the order of several darcies, confirming that they can act as significant reservoirs in oil and gas fields. Channel Thalweg Deposits:Initially, point bar growth produces a single-thread sand body that migrates laterally at the channel bends, maintaining a constant thickness.

Introduction

The investigation of sediment dynamics on continental margins is of major interest as sediments deposited in these areas can provide a high-resolution record of pastclimatic changes, and also host some of the world's major hydrocarbon reservoirs. Important architectural elements of continental margins are large submarine slides and sub-marine canyons and channels; these elements are two of the major targets for marine geological research at the present time.Wavelet (Mathematical Microscope) analysis of seismic data is made fashionable for thin bed precise subsurface imaging and interpretation. 3D seismic data interpretation for subsurface imaging of thin bed contourite systems is integral part of research work. Seismic expression of bottom current deposits from that of other related deepwater sediments (turbidites, hemipelagites, debrites, etc.), and to maximising the information that can be derived from seismic data. A wide variety of seismic facies are common in contourites, most of which are equally present in turbidite systems. Seismic facies associations that may be typical of contourites are still to be defined. Seismic characteristics also depend very closely on the methods of seismic acquisition and processing. Sediment waves and channels are very common both in contourite and turbidite systems, and not specifically diagnostic of either system. Slope deformation, sediment creep, and large-scale water-escape may cause a hummocky seismic facies that can be misinterpreted as sediment waves. The identification of hydrocarbon reservoirs from seismic data is a key issue in the oil industry. This is often difficult to achieve in deep-sea sediments, where similar morphologies can prove to be sand-bearing or mud bearing (e.g. the seismic mounds that characterize the basin-floor fan and slope fan. Contourites are widespread throughout the deep sea, ranging from those that build up individually distinct bodies (mounded drifts) to those that occur closely interbedded with other deep-water facies. Although seismic data should not be used to make a firm identification of contourites without supporting evidence, much progress has been made in determining the combination of seismic criteria that best represent contourite deposits. Texture Segmentation of a 3D Seismic Section with Wavelet Transform is employed for pattern recognition. Because of the segmentation, zones of different internal stratification are identified in the seismic section. This recognition is based on the comparison of the 3-D seismic data with the reference patterns extracted from the representative areas, characterized by different textures. In splicing 3-D seismic data, consistent processing is one of the key technologies because it has a great effect on imaging quality.Seismic geomorphology goal is to look for and recognize geologically or geomorphologically meaningful patterns in plan view as well as in section view. Seismic geomorphology, the extraction of geomorphic insights using predominantly 3D seismic data, is a rapidly evolving discipline that facilitates the study of the subsurface using plan view images. A variety of analytical techniques is employed to image and visualize depositional elements and other geologically significant features. Rock visualization stereoscopic volume rendering computer-based display and visualization of 3D data began to take hold making true 3D interpretations possible. Methods evolved for generating horizontal and flatted slices, arbitrary traverses

,wavelet attribute extractions and mapping, and rapid analysis of large complex data volumes. A geological feature must have an expression that is scientifically reasonable in multiple dimensions. Analyses of section view integrated with plan view images represents the integration of seismic stratigraphy with seismic geomorphology. Pattern recognition, involving the interpreter being able to recognize geologically significant features in plan view on 3D .the seismic data, is critical to the seismic geomorphological approach. In conjunction, it is also essential to cross reference plan view with section view images, thus integrating the geomorphology with the stratigraphy. Seismic geomorphology is a rapidly evolving discipline, benefiting from the rapidly accelerating widespread availability of 3D seismic data. Sequence stratigraphy has proven to be an extremely useful predictive tool in the search for hydrocarbons along the continental margins.

Eventually an equilibrium planform geometry is reached and the channel aggrades without further bend movement . The resultant 3-D geometry is predictable and suggests that facies sequences vary as a function of bend position. The thalweg deposits at crossover points are near-vertical; the bend apex is characterized by a lower sequence extending obliquely outward from the inner part of the bend and a vertical upper sequence. Longitudinal profile of submarine channels: The thalweg-depth profiles (i.e. longitudinal profile) of submarine channels are generally measured at the channel thalweg (i.e. the deepest point of a channel) along the channel axis. The influence of mass-transport deposits (MTDs) on submarine-channel development :Mass-wasting processes have a significant impact on seafloor morphology and sediment distribution on continental slopes. They evacuate large volumes of sediment and are capable of changing seafloor topography, ultimately controlling the distribution of turbidites that may form important reservoirs for hydrocarbons. The responses of submarine channels to tectonic structures :The behaviours of turbidity currents, such as erosion, bypassing or deposition, are closely related to variations in seafloor gradient, the development of submarine channels is thus strongly influenced by variable seafloor topography generated by active faults, folds, and gravity tectonics such as mud and salt diapirs.

Mass Transport : In particular, the geohazard potential of submarine slides is intensely studied as they can trigger tsunamis and destroy offshore installations, especially as hydrocarbon exploration and production venture into increasing water depths. Marine geology studies about submarine mass-movements have demonstrated their relevance in building and evolution of continental margins. This is because mass-movements represent the main mechanism of sediment transport from continent to deep-sea areas, and one of the most common geological hazards in submarine environments. They occur in all the sea and oceans of the world, and may develop in all the physiographic environments , from the shelf, slope, continental rise to deep sea areas. Their resulting deposits have variable dimensions, from metric to several hundreds of km in length, and from centimetric to severel tens meters of thick. Their sedimentary record informs about variations of glacioeustacy and hinterland sediment sources, occurrence of meteoceanic processes that can affect to seafloor, active tectonism and seabed fluid flow related rocesses. The acknowledgement of submarine sedimentary instabilities combining multidisciplinary and multiscale approaches. The main topics for mass-movements investigations: characterization of continental margin and historic register of the instabilities on a continental slope; definition of the dynamics of slope failures; study of physical and mechanical properties of sediments; and definition of forces that may trigger submarine mass-movements and determinate their evolution, etc. Seabed instabilities ranging from smaller slumps to enormous retrogressive (back-stepping) underwater slides have been mapped as slide scars and Mass Transport Deposits (MTDs) on slope inclinations less than 1 to 3° in glaciated margins and on the major river deltas.

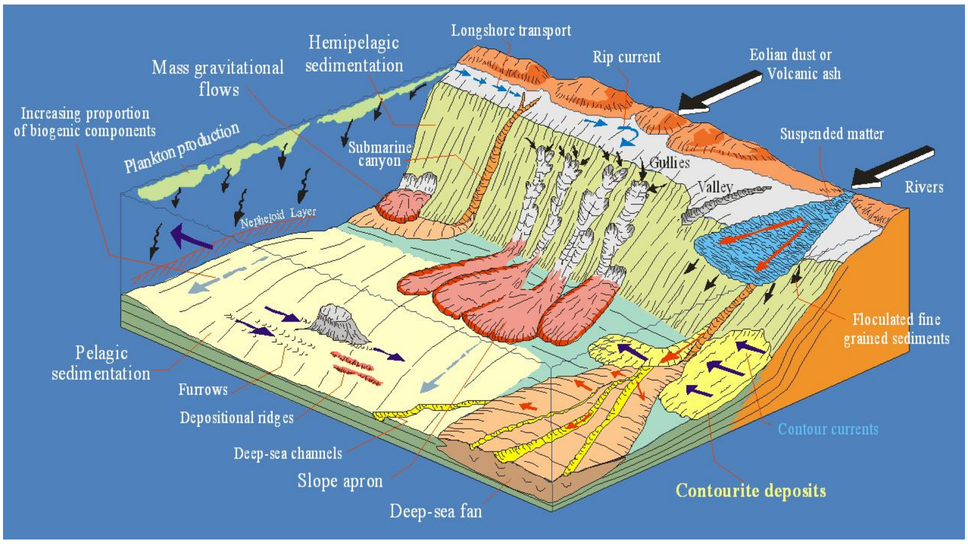


Figure1: Contourites (Courtesy by Stow, D.A., 2011).

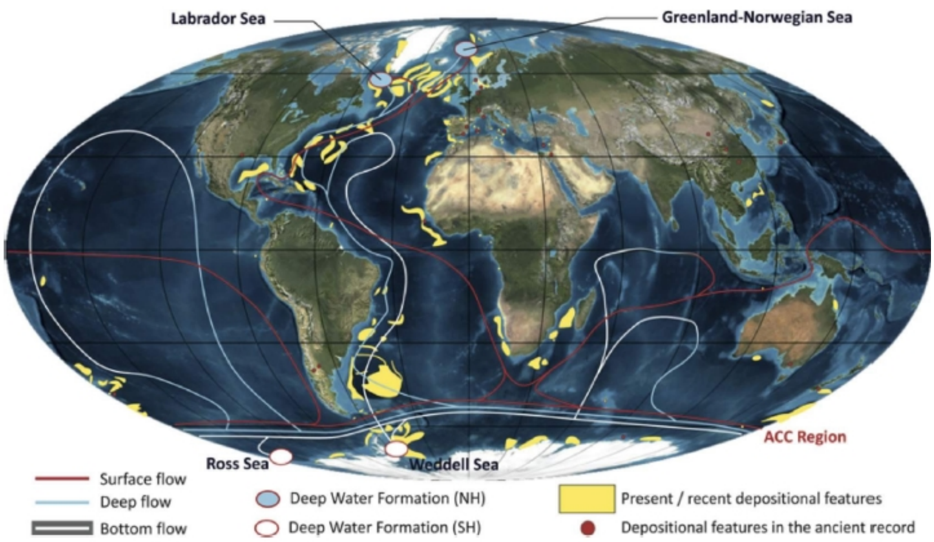
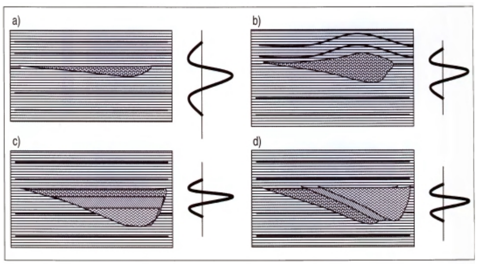


Figure 2. Global thermohaline circulation and occurrence of large contourite deposits in the present ocean basins (yellow areas) and in the ancient sedimentary record (black points), Rebesco et al. (2014)

Geophysical signals are multiscale and nonstationary in character. Seismic signal processing is an important task in geophysics sounding and represents a permanent challenge in petroleum exploration. Although seismograms could in principle give us a picture of a geological structure, they are very contaminated by spurious signals and the ground roll noise is a strongly undesired signal present in the seismograms – it does not carry physical information about the deep geological structures. Multi-scale morphology has a wide range of applications in seismic data processing. It can be applied to suppressing surface waves and interfering waves , detecting seismic fractures ,and removing multiple waves. Applications Multiscale signal & image processing seismic subsurface imaging ,Multiscale full waveform inversion, multi scale seismic tomography, seismic image processing -analysis/understating-interpretation(splicing & quilting); 3D seismic attributes enhancement and detection by advanced technology of image analysis,image that contains large scale edges as well as textures with small scale features, Image structure analysis for seismic interpretation; 3D seismic image processing for unconformities and Graphic processing unit, edge detection -sobel filter,etc. Multiscale seismic characterization of marine sediments by using a Wavelet transform- wavelet-based method to characterize acoustic impedance discontinuities from a multiscale analysis of reflected seismic waves continuous wavelet transform(CWT) of a seismic trace involving such a finite frequency bandwidth can be made equivalent to the CWT of the impulse response of the subsurface and is defined for a reduced range of dilations, controlled by the seismic source signal. In this dilation range, the multiscale seismic attributes are corrected from distortions and we can thus merge multiresolution seismic sources to increase the frequency range of the mutliscale analysis. Seismic attributes have been widely used in hydrocarbon exploration and exploitation. However, owing to the complexity of seismic wave propagation in subsurface media, the limitations of the seismic data acquisition system, and noise interference, seismic attributes for seismic data interpretation have uncertainties. Especially, the antinoise ability of seismic attributes directly affects the reliability of seismic interpretations.



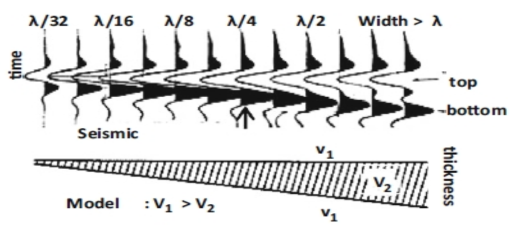


Figure3(left) : Attributes response to channel features preserved in the geologic record,(a) Below thin – bed tuning , with homogeneous fill and no differential compaction. Only the amplitude changes ,(b) Below thin bed tuning, with homogeneous fill and differential compaction. Curvature and amplitude change; waveform does not change. (c) above thin bed tuning, with heterogeneous horizontal fill and no differential compaction. Curvature does not change, amplitude and waveform do change . (d) above thin bed tuning, with heterogeneous aggradation fill, Curvature ,Amplitude And Waveform all change

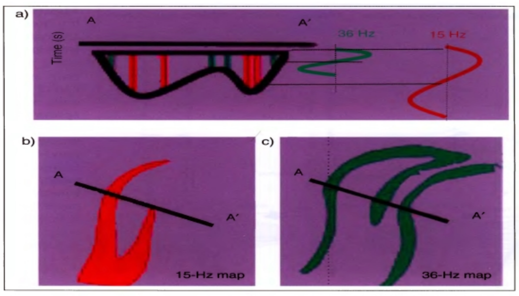
Figure4(right): Illustrating tuning thickness with Widess wedge model. Maximum amplitude is seen at $\lambda/4$ thickness known as 'tuning thickness' and defi nes the limit of a 'thin bed'. Below this no change in waveform width is noticed but a gradual decrease in amplitude is seen with thinning of wedge that offers a link between amplitude and thickness of thin beds (Modifi ed after Anstey 1977)

Theory : Wavelet Transform : Seismic Intepretation Pattern Recognition

2-D wavelet transform is employed for image processing.**Wavelet Transform (WT)** uses a window function whose radius increases in space (reduces in frequency) while resolving the low-frequency contents of a signal . WT is an analysis tool well-suited to the study of multiscale, nonstationary processes occurring over finite spatial and temporal domains.The integral (continuous) WT of a function $f(t)$ with respect to some local base function (wavelet) ψ is defined as $W(b,a) = \frac{1}{\sqrt{a}} \int f(t)\psi^*\left(\frac{t-b}{a}\right)dt, \quad a > 0$

where ψ^* is the complex conjugate of ψ. The parameters b and a are called translation (shifting) and dilation parameters, respectively. $\psi_{a,b}(t) = \frac{1}{\sqrt{|a|}}\psi\left(\frac{t-b}{a}\right) \quad a,b \in R;\ a \neq 0$ Although $W(b, a)$ provides space–scale analysis rather than space–frequency analysis, proper scale-to- frequency transformation allows analysis that is very close to space–frequency analysis. Reducing the scaling parameter a reduces the support of the wavelet in space and hence covers higher frequencies, and vice versa. Therefore, 1/a is a measure of frequency. The parameter b indicates the location of the wavelet window along the space axis. Thus, changing (b, a) enables computation of the wavelet coefficients W(b, a) on the entire space–frequency plane.A required condition for ψ is that all wavelets must oscillate, giving them the nature of small waves and hence the name wavelets.

The Continuous WT separates out the frequency components of a signal. It is therefore important that the wavelet used gives the best resolution in frequency.



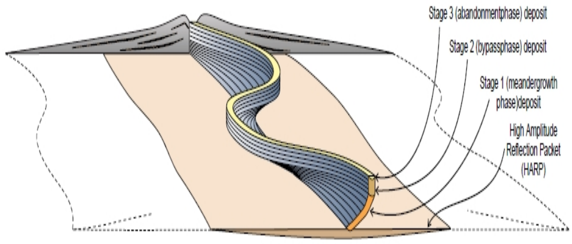


Figure5 (left): a schematic diagram showing the interrelationship between thin bed tuning and the amplitude of spectral components through an idealized channel. (a) a vertical cross section , and (b) spectral components at a higher frequency and (c) at a lower frequency, shown in map view. On the thineer flanks, thin bed tuning occurs at the higher frequency components(in grren). In the thalweg or centre of the channel, thin tuning occurs at the lower frequencies(in red) . After Laughlin et al (2002)

Figure6 (Right): The **thalweg deposits** at crossover points are near-vertical; the bend apex is characterized by a lower sequence extending obliquely outward from the inner part of the bend and a vertical upper sequence .

Seismic phase character: Seismic geomorphology can be an indicator of depositional elements and depositional processes. For example, a channel pattern seen in a coastal plain sequence implies a fluvial process. However, it is also desirable for seismic data to be calibrated to lithology so that sediments of a depositional process can be evaluated and added to the analysis. A channel filled with sand or shale could imply an active channel or an abandoned channel, with completely different significance for hydrocarbon prospecting. With better correlation between amplitude and lithology, both sedimentary rocks and depositional processes can be studied using seismic data, and seismic sedimentology becomes possible. Industrial standard seismic data is zero-phased. A zero-phase seismic trace is symmetrical to a single reflection surface, with the maximum amplitude approximating impedance contrast . Zero phase data are ideal for lithofacies identification on an unconformity or in a thick bed. However, for seismically thin depositional units, amplitude traces from zero-phase data become asymmetrical and are more difficult to tie to lithology-indicative wireline logs .

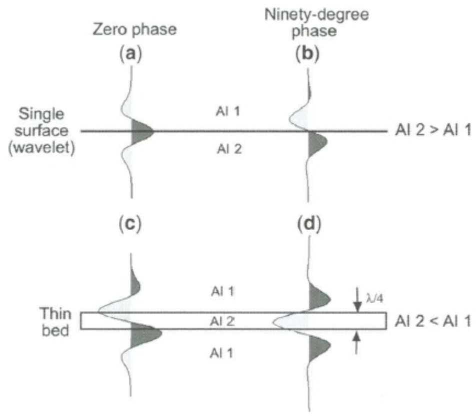
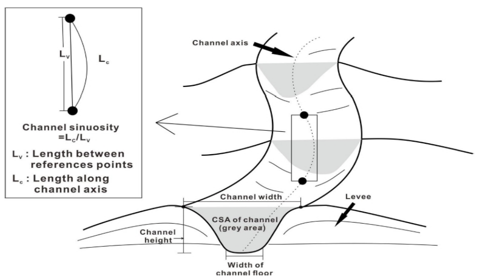


Figure7.: Phase control of seismic waveform to a geological object. Corresponding to a (0 ~ phase) Ricker wavelet, seismic reflection is symmetrical to a single surface (a), but is antisymmetrical to a seismically thin bed *(*h/4 in this case, (c). In contrast, a 90 ~ phase Ricker wavelet results in a reflection that is antisymmetrical to a single surface (b) but symmetrical to a thin bed (d). The 90 ~ phase data are optimal for thin-bed lithological interpretation because the maximum amplitude (trough) points to the centre of the bed, seismic polarity approximates lithology, and stratigraphical resolution is higher (narrower side lobes).

The use of curvature attributes for defining stratigraphic features of interest on horizons mapped in three-dimensional seismic data. Curvature is a two-dimensional property of a curve that quantifies how much the curve deviates from a straight line. Many different types of curvature may be defined for a surface, and these can be more useful than dip, azimuth or even 'conventional' (i.e. second derivative) curvature analyses for defining subtle structural or stratigraphic features of interest. Mathematically, it is also the reciprocal of the radius of curvature, i.e. the curvature is high for a small radius of curvature. Curvature is better than the conventional dip and azimuth measures for defining subtle structural and stratigraphic features. Curvature analysis of surfaces removes the effects of regional dip, thus emphasizing small-scale features that might be associated with primary depositional features or small-scale faults. A tilted planar surface has dip but no curvature. When a surface is steeply dipping, for example on the limbs of a fold, high dips can obscure subtle features on the surface. This problem is commonly referred to as 'dip saturation'. Curvature analysis identifies deviations from a planar surface, regardless of whether the surface is horizontal or tilted. The sign (positive or negative) of the curvature also conveys shape information (convex-up versus. concave-up, respectively).



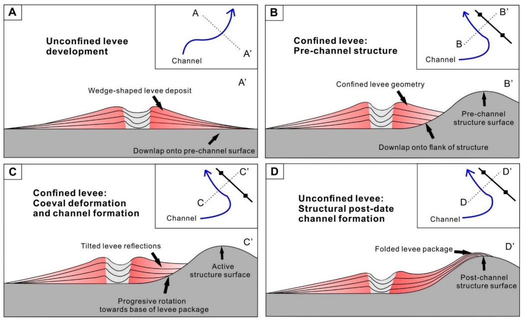
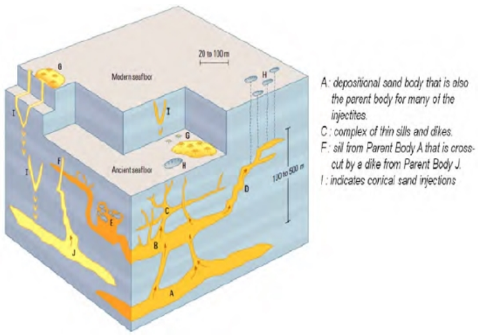


Figure8(left):. Schematic representation of morphological analyses commonly used in the interpretation submarine channels. Parameters analysed include the channel-floor width, channel width, height, and the calculation of cross-sectional area (CSA) and channel sinuosity.
Figure 9(right): Schematic representation of the responses of levee morphology to the effects of tectonic deformation (from Clark and Cartwright, 2009).

Wave Equation in Differential Form: Fractional Derivatives (seismic wave attenuation) appear in Biot theory which is essential to describe wave propagation in multi-phase (porous) media from the seismic to the ultrasonic frequency range. Since fractional derivatives appear in Biot theory, which are related to memory effects at seismic frequencies. Porous media are anisotropic due to bedding, compaction and the presence of aligned microcracks and fractures. In particular, in the exploration of oil and gas reservoirs, it is important to estimate the preferential directions of fluid flow. These are closely related to the permeability of the medium, and consequently to the geometrical characteristics of the skeleton. The Wolf Ramp: Reflection Characteristics of a Transition Layer-The modern use of spectral decomposition has shown that reflection events in practice are always frequency dependent, a phenomenon we call reflectivity dispersion. This can often be attributed to strong interference effects from neighbouring reflection coefficients of the classical type (i.e., parameter discontinuities or jumps). However, an intrinsic frequency dependence from a single layer is possible if the contact is not a jump discontinuity but a gradual transition.Wolf Ramp- Reflection From Transition Zone reflectivity dispersion which refers to frequency dependence of a normal incidence reflection effect.There are few causes for reflectivity dispersion , e.g. rough surface scattering, reflection from an interface porous media,vertical transition zone.Biot Reflection the great problem of reflectivity dispersion arising from a poroelastic contact in earth which acts as DHI Direct Hydrocarbon Indicator.



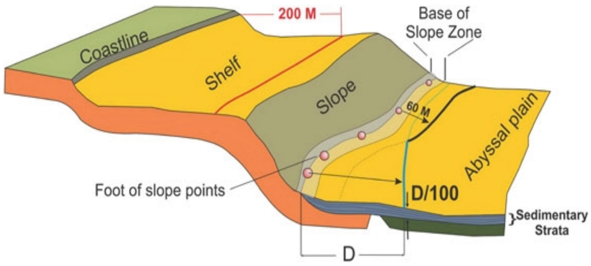


Figure10: Sand Injection Featrures (by Braccini et al. 2008)
Figure11. Elements prescribed in article 76 for defining the outer edge of the legal continental shelf: (1) the foot of the continental slope plus 60 nautical miles (M) (Hedberg formula), or (2) the distance (D) from the foot of the continental slope where it is equal to 1 % of the thickness of sedimentary rocks (D/100) (the Gardner formula)

Conclusion

IGCP 432(Turbidites Deepwater Hydrocarbon Channel-Thalweg Krishna Godavari Basin –India(IN), AO, NG, MX, BR, AU,MZ etc;,IGCP619 Contourites Hydrocarbon -Krishna Godavari Basin-India(IN), AU, TH, VN, CN, MY, ID, IL,LY,MA, AO, GH,NG/ST-JDA BR,TT,MX,VE,US,CA,NO,NL,DK,IE,MZ,etc. Projrcts play a pivotal role in deep water hydrocarbon exploration with a view to energy security of the world.

Mass Transport Deposit (MTDs) and Mass Transport Complexes (MTCs) processes are important in slope deposits and with a view to global geohazards monitoring and natural resources (hydrocarbon). The Role of Submarine Landslides in the Law of the Sea:Article 76 of the United Nations Convention on the Law of the Sea Recognizing that submarine mass movement is a slope process that also influences the shape of the continental margin, several nations have successfully argued that the downslope termination of mass transport deposits assist in distinguishing the continental slope from the rise and abyssal plain. The Commission on the Limits of the Continental Shelf have now made recommendations for a number of coastal States with rift margins, transform margins and subduction margins where the extents of surficial mass transport deposits were used to help delineate the base of slope zone within which the foot of the continental slope is chosen.The Commission on the Limits of the Continental Shelf (CLCS); the body that reviews extended continental shelf submissions under the UN Convention on the Law of the Sea, in its guidelines and decisions to date, has encouraged coastal States to use scientific arguments in defining the elements of a continental margin and thereby delimit its outer edges. One of the critical metrics in this process is establishment of the “foot of the continental slope” (FoS) and submarine landslides can assist in identifying this metric.In sedimentary geology, ground penetrating radar (GPR) is used primarily for stratigraphic studies where near-continuous, high-resolution profiles aid in determining: stratigraphic architecture; sand-body geometry, and correlation and quantification of sedimentary structures,etc. GPR is also efficient for ocean floor mapping and sub seabed imaging of sediments,marine sedimentary depositional sustem study (turbidites-channels, contourites- potential hydrocarbon system). Sand injection complexes have a tri-partite organisation of parent units, an intrusive complex and seafloor/surface extrusions. Within the intrusive complex a lower dyke zone, sill zone and upper dyke zone are present that with varying levels of representation are present in all injection complexes.Soft-sediment remobilization, injection and fluid flow processes and their products such as sand injectites, mud volcanoes, pipes and pockmarks constitute component of sedimentary basins. Due to the discontinuous nature of sand injectites it is challenging task to detect by seismic prospecting. Seismic resolution of injected sands with sill or dyke geometry is possible, providing the sand bodies are sufficiently thick to give a tuning response or discrete reflections from top and base of the body.The limit of detection is strongly dependent on acoustic impedance contrast between sand and the adjacent fine grained strata. Seismic Unix (Chirp,Boomer USGS) is employed for SBP signal processing .SEABED2030, General Bathymetric Chart of the Oceans (GEBCO) Forum for Future Ocean Floor Mapping is integral part of my research work. Mathematical Morphology-Top Hat Transform, Fractional Fourier Transform, Fractional Wavelet Transform, Hilbert-Huang transform, Partial Differential Euations(PDE), affine transformation, Non Negative Matrix Factorization-Deblending, Bootstrap, Quaternion,etc. are employed for image processing and analysis of acoustical oceanography (underwater acoustics) data.

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http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/international-geoscience-programme/igcp-projects/
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I am thankful to geophysical data providers for research work
I have login/password approved by **www.ig.utexas.edu/sdc** for seismic data.
I also received Seismic data in LTO 4 tape (two) from **www.ig.utexas.edu/sdc**.
Academic Seismic Portal at UTIG - Institute for Geophysics, **University of Texas at Austin**
Antarctic Seismic Data Library System (SDLS)**http://diam12.ogs.trieste.it/SDLS/index.php**
Antarctic Seismic Data Library System (*SDLS*) – Ogss *dls.**ogs.trieste.it** (I have login/password)*
CNSOPB Data Management Centre ,*www.cnsopbdmc.ca*
Canada-Nova Scotia Offshore Petroleum Board
wiki.seg.org/wiki/Open_data
SEISMIC UNIX (Chirp,boomer USGS) is employed for Sub-Bottom Profiler (SBP) signal processing. **Seismic Unix** ,*www.seismicunix.com* , www.cwp.mines.edu/cwpcodes SEISMIC UNIX SCRIPTS CHIRP /BOOMER
https://pubs.usgs.gov/of/2001/of01-165/HTML/SEISUNIX.HTM
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