Lecture 15
Offshore Investigation

Welcome all to lecture fifteen of the course “Sub surface exploration”, introduction and technique involved. So, so far we have discussed like different phases of investigations, where investigations are required, what are the phases of different, different phases of investigations? Then we will, when we go for detail investigation, what are the classifications of investigation? Then we move to module 2, where we had discussed about Geotechnical investigation, so different kind of geotechnical investigations, what are methods? How you will do the field exploration? How you interpret the results? That we have discussed in module 2. Then in module 3, we have discussed about geophysical investigation techniques, starting with, seismic refraction, survey seismic reflection, survey to more advance, electrical resistivity, gravity measurements, exploration so and in so fourth and then at every stage we tried to solve some numerical problems, so that we can understand based on may be from very simple to complex measurements, how we will be able to understand that different kinds of

materials available beneath the surface as well as understanding the characteristics of the material. So today we are going to start module 4 that is on “Offshore Investigation”, so far we have discussed about all the methods particularly related to onshore or other structure which are going to be constructed on actual land masses. But we can see now a days, we are hearing in the news, news papers also and in lot of technical reports like, because of, land constants in many of the location because of contaminated lands, because of considerably large requirements from land mass or proposed site is required, most of the time whenever we are going for any specific kind of structures or may be mega structures, we are going now a day’s offshore. So offshore is particularly when you are going away from the land marks into the ocean, depending upon the depth, depending upon the distance from the coastal line, the choice of the foundation, that kind of structure we call, can we categorize further in to different category. So over all it is called as offshore investigation, offshore structures. So offshore structures can be for different kind of purposes, which we are going to discuss today and depending upon the choice of the of the structure, depending upon the requirement of the structure, where we are going for the offshore, the requirement for the particular investigation technique, may change from one to other.

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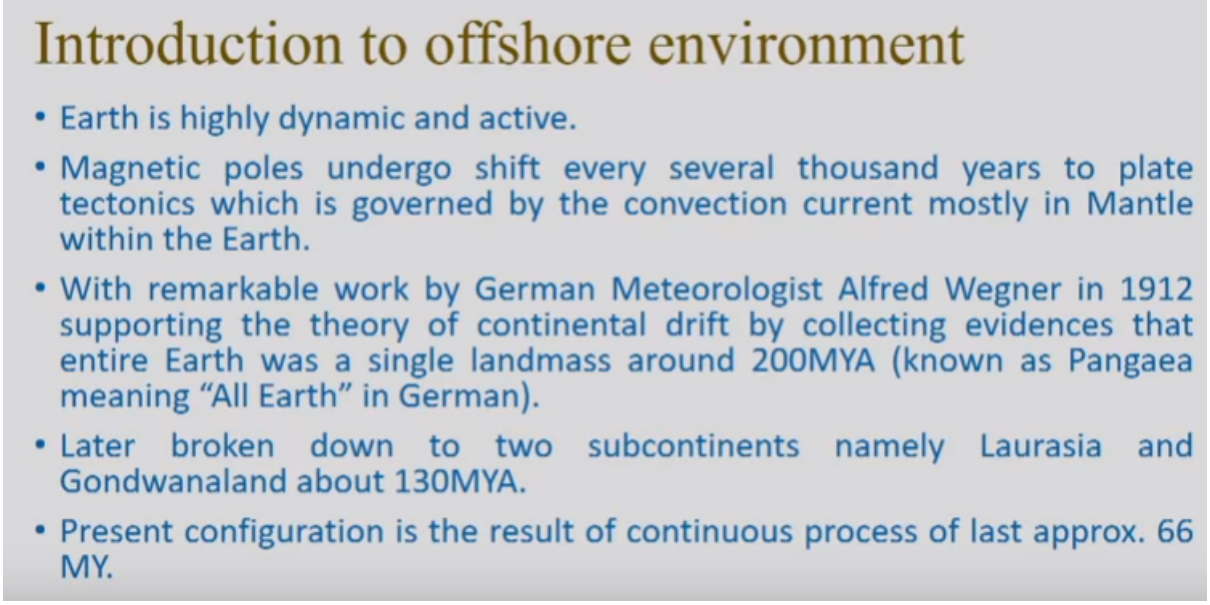

So introduction to offshore investigation or offshore environment are that we know it is very dynamic in nature, though from the space it looks very stable but if you start understanding the various process happening across the earth, along with the altitude, also you can see the magnetic poles or the magnetic field across the earth, which keeps on shifting every several thousands of years, so present configuration of magnetic north and magnetic south pole may or may not remain same after several thousand years from today and which was not there even several thousand years prior to today. So this is like about a magnetic pole which is happening along the surface and everywhere along the earth. Starting with that if you are going deeper into the earth, this remarkable work is particularly done by German Meteorologist Alfred Wegner 1912. He highlighted based on the collected evidences like the entire landmass of the earth, wherein some particular geological time attached towards each other or attached into a single landmass as per the continental drift theory, it was around 200 million years. Why I am telling like though we are considering it as very stable but lot of process are happening as a

result of those processes different characteristic of the exploration site is governing its stand characteristic, it is governing its deposition characteristic, its weathering characteristic and so on and so forth will be responsible, why we should go for particular restoration whether it is onshore or whether it is offshore, so starting with 200 million years ago the entire landmass like now we are seeing like somewhere Australia is there, somewhere Africa is there, somewhere India is there and America is there but around 200 million years ago, entire landmass was one, which is called as "Pangaea", which in German is known as, "All Earth", later in 130 million years ago, 'MYA' is million years ago, this is how generally we refer to any timescale in, in geological time. So the entire Pangaea is divided further into two landmasses, one is called as, 'Laurasia', other one was called , 'Gondwanaland', which further broke down into several smaller continents or major plates, minor plates, detail of that you can understand may be from any geological book or seismology book. Present configuration whatever we see, like where India is there, Africa is there, Australia is there, America is there, South America is there, it is , it is as a result of the various process which are happening at various depths and even the impact of temporal changes, special changes, happening along the earth surface and even other governing processes, so whatever present configuration we are see it is as a result of continuous process which as happened in last approximately 60 million years. See, even the Himalayas when we talk about, we assess the age of the Himalayas close to 50 to 52 million years, since the Indian period and the Eurasian period come in contact with each other as a result of which, as a result of this collation Himalayas kept on building, may be around 50 to 52 million years ago that process has started and so far, earlier it was like very levelled surface and because of the cologne started raising now we can see Mount Everest which is the highest peak in the Himalayan range, as a result of this collation as well as we also witnessed lots of earth quakes happening all along the Himalayan boundaries. So same way this is about the process happening towards landmass getting converted into hilly terrains or may be hills. On the other end you have oceans, so some processes are happening along the oceans also, which is governing. The sea bed characteristic, which is governing different topographical features, which are developing along the ocean surface also. That is more important to understand, considering the topic of offshore investigations or offshore structures into consideration.

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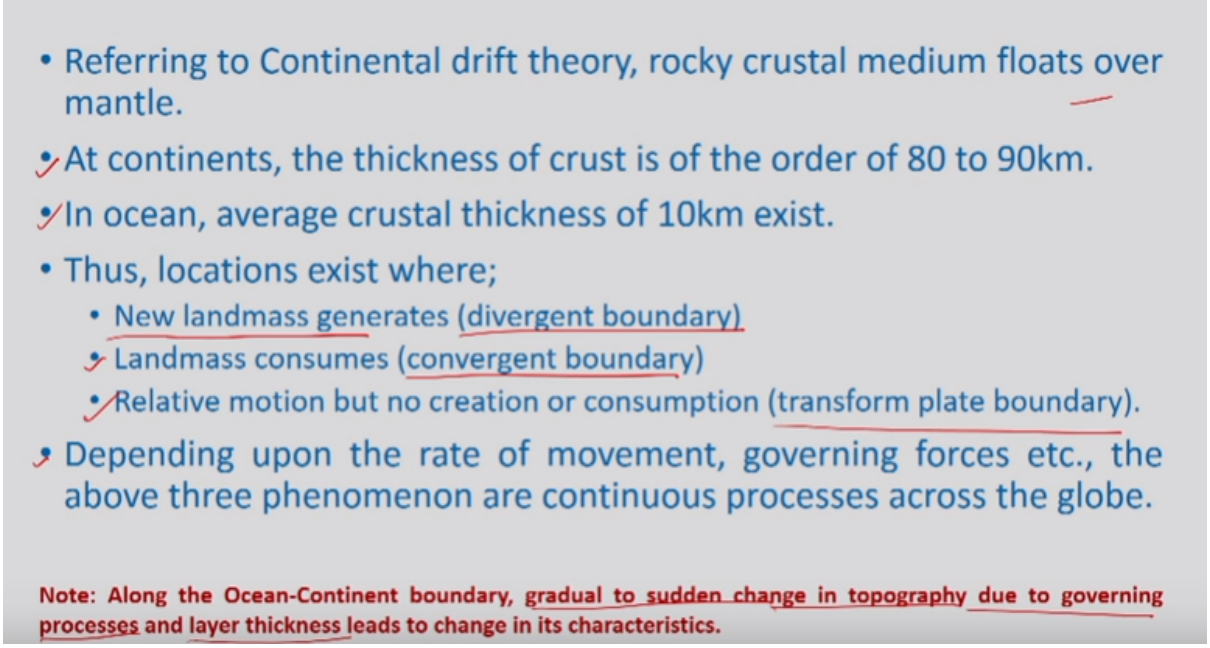

So, referring to Continental drift theory, which talks about like because of if you understand different kinds of layers which are available along the earth, starting from the Crust, that is the upper most layer to the core which and each of this layers like crust, mantle core are available which are available with different physical and chemical properties, as well as the physical phase in which it is existing, some are in solid, some are in molten state, some are in more viscose, some are in less viscose, as a result of which in addition to this we are having very significantly higher temperature, as you go deeper and deeper depth, so as a result of which temperature variation in this viscose materials, particularly in the mantle there will be a conviction current, so at the top surface of the mantle, the temperature will be relatively lesser, as a result the material becomes cooler, and starts cooler and heavier and starts settling to the deeper depths, once it reaches the deeper depths again the temperature will be higher, material starts melting, it becomes lighter and again it will come to the surface. So as a result of this continuous process of heating, cooling, heating, cooling what it does, it actually exerts some kind of it actually generates conviction current, which induces some kind of push along the base of the crust medium or the top most layer. As a result of which the continental depth services is like the result of this conviction current there is continuous movement of different plates, whatever we see, Indian plate, American plate and so on and depending upon the governing forces under each plate and if the plate is in contact with other plate, then the conceding the geological age of the other plate, conceding the thickness of the other age, conceding the strength characteristics of the other plates and the other process which are governing the movement of this plate, at some portion you might find plates are moving towards each other, some location plates are moving away from each other, sometime the plates are moving relatively with respective to each other. So as a result of this continuous process, the thickness of the crust like wherever it is moving towards each other, you can see like there will be building up of mountains, so the thickness of that particular location keeps increasing and other location where your ocean the thickness of the crust will be relatively lesser or on an average it has been observed that along continents or in continents average thickness of crust is of order of 80 to 90km. So 80 to 90km thickness of top most layers has been observed along the continents, similarly along the oceans, we can see the average thickness of the

crustal medium is 8 to 10kms. Now this is happening all across the globe it is not possible every where the plates the two continental plates or the oceanic plates or ocean continental plates are moving towards each other or are moving away from each other. As I highlighted earlier there are lot of processes which are governing or which are responsible for the movement of each of these plates, as a result of this process is, as a result of nature of this process, as a result of governing forces which are deriving the movement of a particular plate towards each other, towards other plate or away from other plate, generally the plate boundaries it can be continent, continent, it can be continent ocean or can it be ocean, ocean plates. So two plates whenever at the boundary if you see, you can see a diversion plate boundary, means two plates are moving away from each other as we can see in mid oceanic range. So as a result of divergent plate boundary what will happen the material, the mantle comes up on to the surface, spreads on to the surface and because these two plates are moving away from each other, so the new materials comes on to the surface get settled and the boundary and then the process of movement or the divergent of this plate, this material will move after sometime it will move away from the boundary, new material will settle at the boundary. As a result of this continuous process there will be continuous process of new landmass creation. This is called as, 'divergent plat boundary'. Then you can have 'convergent plate boundary'. So where the two plates are moving towards each other or may be the relative motion of one plate will be more than the other plat that also governs, that is also governed by which plate is relatively softer, which plate is relatively harder or which is relatively older or younger plate, that governs which plate will undergo which plate. So in this particular process that is called as, 'convergent plate boundary', the two plates are converging towards each other or moving towards each other, as a result one plate will be going down or sub ducting other plate will be above that plate. So in this case, because the plate is moving under the other plate, the landmasses is getting consumed. In the first one it was creating, here it is consuming different locations across the globe, if you see the plate boundaries each of this processes is happening will be happening at different, different locations. Now there may be another condition where neither the consumption of landmass nor there is creation of new landmass. So such plate boundaries are called as, 'transform plate boundaries,' such boundary generally exists whenever the rate of convergent is changing between two plate boundaries, so you can have some kind of relative motion between those two convergent or divergent plate boundaries, having different rate of movement. So this is called as, 'transform plate boundary'. This process we have to be very clearly understandable, like this process of, divergent, convergent or transformation is a continuous process which is happening since the geological time scale like which we discussed about 66million years of present configuration and it has started as early as 200 million years after that. So as a continuous process, as a result of which there are three types of plate boundaries has been highlighted by the geologists even seismologist along the continent and ocean plate boundary, now we're talking about initially we talk about onshore structures, the structure which are actually located on actual landmass, now we are talking about some structure which are on in the ocean, so there is a always the transition from continental land, continental landmass of continental boundary to oceanic plate boundary, so along the ocean and continent boundary or interface there will be gradual to sudden change, so it can be gradual change, it can be sudden change in the topography, i am talking about the interface, so there is a continent , there is a ocean and along between the two the transition zone promotion applied to the continent continent and ocean is there any graduate to sudden change in the topography of the

medium due to governing processes one baby the plate movement and other maybe because one plate it may be at one location it might be sub ducting under that but it might be other location at transformed boundary with the oceanic plate this is governing what kind of plate boundary, what kind of transition zone will be there that is between the ocean name plate and the adjacent continental plate it is it is generally govern by the process is happening at the plate boundaries and the layer thickness. As I mentioned here sometime the oceanic crust can be high as 10kms, continental crust can be high as 80kms and more than that. As a result of this there will be gradual change in the medium characteristics of the continental plate and the oceanic plate also. So this also governing whether the topography will be changing suddenly or gradual change will be there in the topography of the medium.

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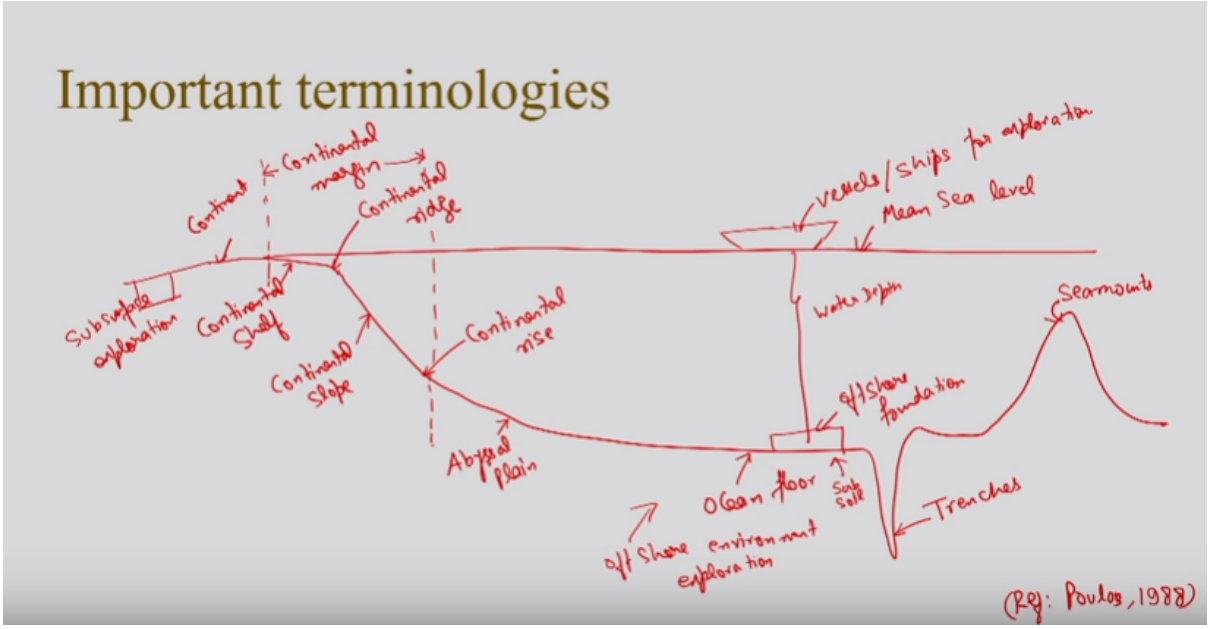

Now important terminologies, we discussed about like oceanic plate is there and every time whenever we see ocean we always see in terms of mean sea levels, which looks like more or less stable, unless you consider the effect of gravitation pulled by moon or sun, but what is happening along beneath earth's particularly along the ocean we are going to see here, so that, that will give you better idea about oceanic floors. So if we consider like this is your oceanic plate, then you are having kind of this then you can have something like this, this is I am referring to continent, this I am referring to ocean, depending upon the extant of continental plate or oceanic plate, there will be always a margin. What is happening here if I mark here, the mean sea level, there can be seamounts, kind of partial to very high altitude deposition of sediments then you can have trenches here which are possible critical example you can see again with respect to mid Ocean reach, in the Pacific you can refer to it here, here you can see there is gradual change or gradual transition from continental plat to ocean, so this gradual change is called continental shelf, I am just writing here the terminologies, shelf which is you can considered the summer portion of continental plate, now there will be again release from where there is some gradual to sudden change in the belt or the topography of the medium, this is called as

continental ridge, then you are having again some some again from this location till this location again there is more or less same changes, same rate of topographical change, this is called as continental slope, this I can give reference, ok this is continental slope, again this is continental rise from where again you are having change in the slope, like till hear it was Steep change and then again it became gradual change and then you can have abyssal plain, wherever it is more or less same, like very gradual change in the oceanic floor is called as abyssal plain. So the arrange, the distance between continental rise and starting of continental shift, this location known as continental margin, like this gradual what I should here most of the time it will be like natural transition from continental to submerge portion of the continent, at times very very rare, it can have certain change also this name is called as continental margin, considering portion of continental shelf and then continental slope in between the continental shelf and continental slope there will be continental ridge, from where that the slope is changing gradual to sudden. Now why important it is again so as you go away further from abyssal plain, you can have may be some seamounts so you can have terrains also , so, what what important thing here to be understood is, though the mean sea level looks very normal, very level but if you start exploring because many of us while going to the schools are not very much aware about offshore environment, so this is going to give you clear idea about like to the mean sea level looks like very levelled one but as you go deeper into the sea floor there are a lot of the topographical changes happening, it can be gradual, it can be steep, it can be again some kind of narrow but very significant change in a topographic then it can be it can be below the surface also, above of the surface likes, seamounts, it can be trenches and so on and so forth, as a result of which you can understand the topography of the oceanic floor is also not remaining levelled or it's not having uniform. In addition to the topographical features even the subsurface material like here I am talking about ocean or oceanic floor. Whenever you kind of go for offshore structure, we will be depending upon the water depth, we will be going even for direct resting the structure on this, even anchored structure, we can go for even floating structure, which will be anchored at the base, or we can go for different kinds of foundation different kind of Anchorage, dependending upon the water depth, depending upon the purpose of the structures, but what important here is you can understand like the topographic of the ocean can have different different features, again if we talk about so when we go for offshore investigation we will be interested to explore, offshore environment exploration, one important consideration which comes into picture when we go for any offshore investigation is like the ecology of the system, like where we are going to construct even like some kind of offshore structure here, during the construction like before the construction there was some there must be some ecological system there must be some aquatic life here. So during the construction, like before the construction there was some, there must be some ecological system, there must be some aquatic life here, so during the construction we have to ensure particularly when you go for any kind of offshore investigation, offshore construction also we have to ensure the effect to the ecology of the surrounding area will be minimal and once the construction is over it should be brought back to its original position or original condition, which was not there during on shore structures, that we are going to discuss in further detail. So this is like offshore foundation, in order to ensure the safety of the foundation very much similar to on shore structure, you have to explore, what kind of soil is there to sea floor subsoil, because the material characteristics are very gradually or sometime very rapidly. Second thing water depth is there, third thing you also take into account of process happening

between the ground surface or water surface of the water surface and you will be having some kind of vessels or shapes which are responsible for, for exploration, so you are actually putting aspiration assembly here at time you can actually do the same, exploration right from the ocean floor downwards itself. So both are possible that we are going to discuss in coming lectures, as a result of this weather it is going to explore this, first of all this medium which is water depth, so lot of processes are happening along this as a result of there will be change in the wave velocity also, the water waves as a result of which there will be change in the chemical characteristics of the water there will be again with respect to depth, other constants also will come into picture that we will be highlighting as we proceed further to this particular topic, but the common feature is like that when we go for offshore investigation like here, you are interested in subsurface exploration here, but there was no ecological consideration in onshore, when we go for offshore, we have to take offshore, ecological consideration moreover the change in the other characteristics will also govern the design consideration will govern the or will pour more and more challenges to your offshore investigations.

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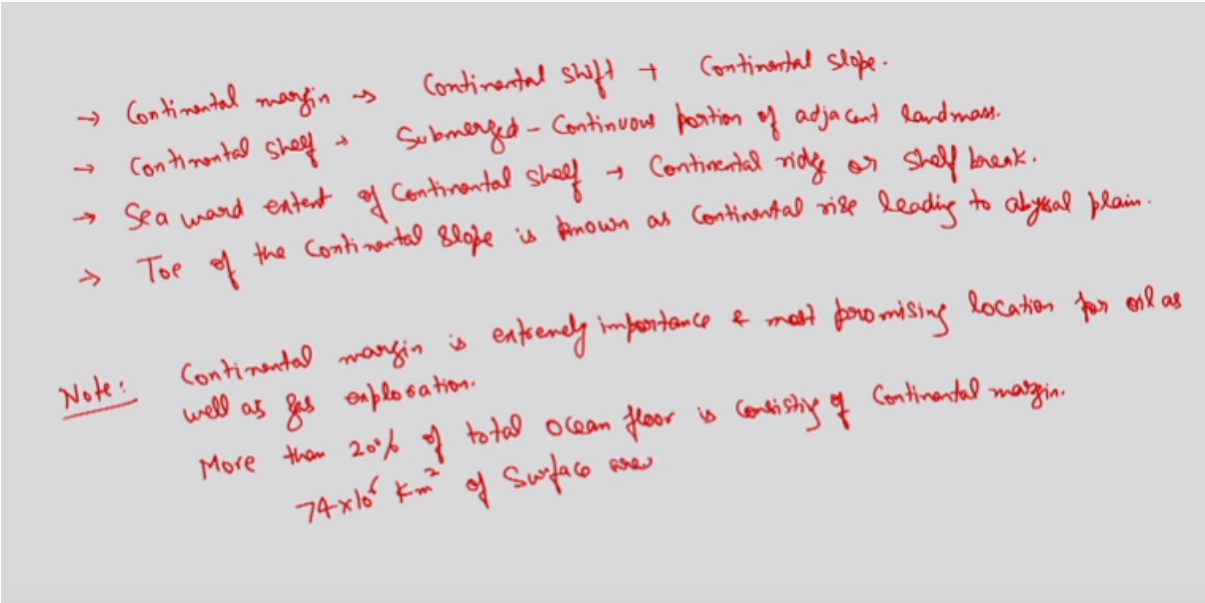

So we discussed about different, different topographical features or characteristics, one is like continental margin, it consists of continental shift, Plus continental slope, you can again refer back to the previous slide to understand this, then you are having continental shelf, which you can understand is submerged portion of submerge, but continuous portion of adjacent land mass, landmass. Because it is submerged, so it will be under water, but it will be called as continental shelf, then you can have a sea ward extent of continental shelf which is known as continental ridge or shelf break then you can have toe of the shelf, toe of the continental slope, is known as continental rise, continental rise, leading to, to abyssal plain. Now why, because we all know now days we are seeing lots of other activities happening while we are going for offshore rather onshore, but primarily the objective where we started going onshore is particularly for oil and gas exploration. so it is it has to be noted here whatever we're discussed in the previous figure, it is to be highlighted here that the continental margin

that is starting from continental shelf to land of the continental and the continental rise continental margin is an extremely important important and most and most promising location for oil as well gas exploration. Whenever like based on particularly geological studies, even portion of seismological studies, people have identified the location global locations of continental margin, particularly the agencies which are responsible for gas and oil exploration, they can go for detailed investigation find out suitability of and the presence of those location. So more than another important thing is more than 20% of total ocean floor is consisting of continental margin. There are maps also like one can refer to the maps generated by say united geological survey, where you get an idea about possible location of continental margin, around each of the major continental plate or so on and so forth. This figure comes out to be, 74 into 10 is to the power 6, kilometre square of surface area. Now based on this itself you can get an idea like , what is the extent of the area along the ocean floor on which one can go for exploration particularly related to oil and gas exploration. Now this is particularly I highlighted whenever we are going for offshore investigation why it is important particularly because you can get oil as well as gas, in the oceans for which people go for detailed investigation and whenever there to take out this particular gas and oil have to go for some kind of permanent structure there to get the structure they have to put some kind of foundation, either it is directly supporting the sea floor or it is anchored foundation but in addition to this the other kind of success which are also called as offshore structures and used for different purposes.

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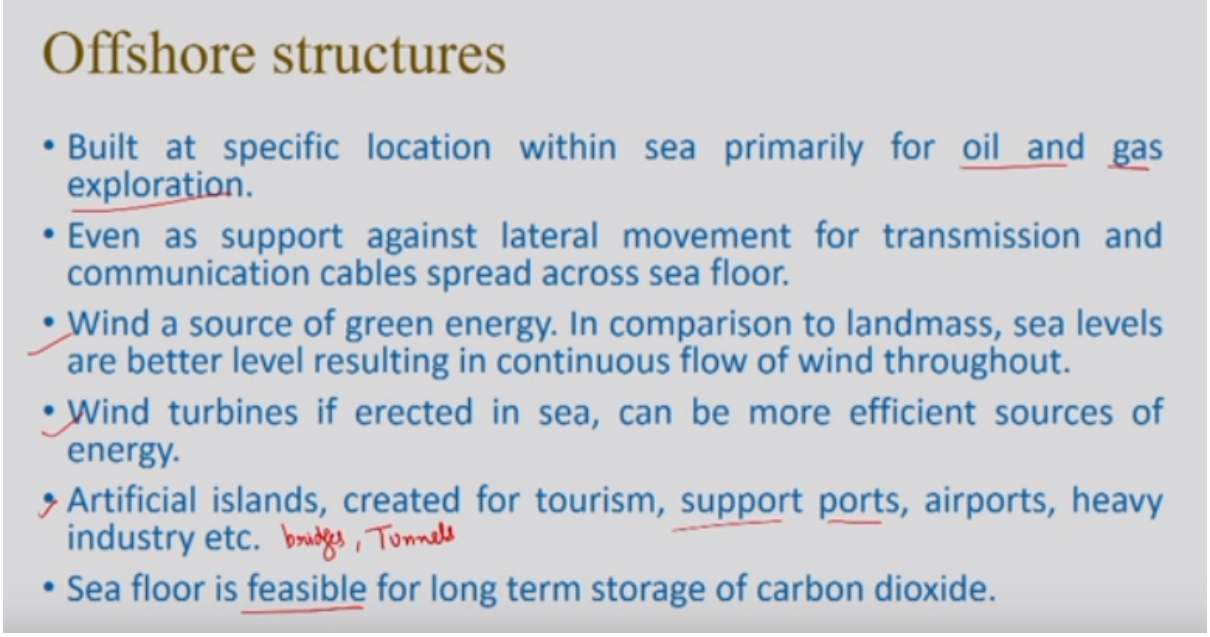

so when you come for offshore structures, it is generally classified as those structures which are at specific location within sea primary for oil and gas exploration, this is like by people starting exploring the sea floors particularly for oil and gas exploration. But later stage people have also used it as a support against lateral movement for transmission cables, like we can see lot of transmission

cables which are running across the sea floors, people inorder to communicate or inorder to like particularly during World war II, lots of transmission cables were laid, along the sea floor so such cables inorder to avoid any kind of movement particularly due to moment of sand dunes baby because of water currents this cable should not keep shifting from one location to another you also provide some kind of lateral supports to this cables, so this are again an additional kind of again to provide some self sufficient mechanism against lateral movement, one should explore what kind of seafloor is available. Then third one the second one is another kind of objective, for which detail investigation which one can go for to design the kind of supports. the third one is wind, it has been understand is the source of green energy, however the direction of wind turbines particularly in major landmasses, first of all landmass available for those location either because of the geological constants or maybe because of limited landmass available, it's very difficult in majority of the location to erect these kinds of wind turbines, on actual landmass, onshore but this can be in comparison to actual landmass erecting such kind of wind turbines will be significantly easier as well as more efficient in erecting these turbine in to seas. another direction of wind turbines you have to go for offshore structures that is called as wind turbines and in comparison to sea the continuous flow of wind can be assured in sea, then the most important thing is many of us can be observed in nowadays like artificial islands, classical example is like palm Islands Dubai has been created for to promote tourism also, to to locate human colonies also there in addition to this artificial islands are getting created as support ports in order to minimise the ship movement along the axis seashore so they can provide additional support ports within the sea, so actual material which are getting transferred or import can be dropped there and again from there it can be transported to the actual main land, through small ships, so those are called as support ports, than air force many of the places we are seeing like people are creating artificial islands and on that artificial Island they are laying airports. similarly for heavy industrial purpose is also, even for bridges also we can add a bridges nowadays particularly like the Bandra-Worli sea link Mumbai, than Chennai recently opened the another sea link, which is quite lengthy, which are, which were not practice maybe one decade or prior to that but nowadays in practice, so this another classical application where one should go for offshore structures and in order to write a particular offshore structures one should go for it and you can also add here tunnels maybe, like lot of places people are going for tunnels, below the the prepared, so once We are going for those kinds of structures, we have to go for proper investigation to ensure the safety of these things. Then sea floor are also used, are also found very feasible for long term storage of carbon dioxide, that also gives to another application one should go for offshore structures, and once you are going for offshore structure you have to go for proper investigation.

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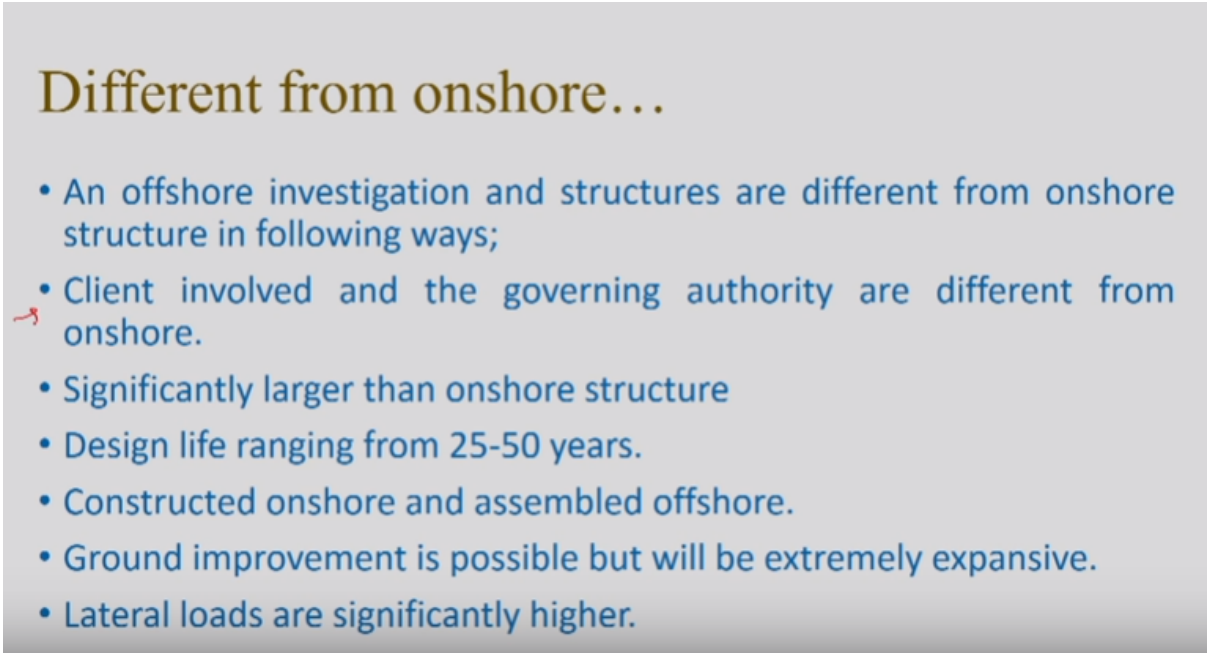

Now how offshore structures are different from onshore structures some of the ways include the clients which are requiring the offshore investigations are different then onshore investigation and the governing authorities as I mentioned here the ecological the clearance from ecological governing agencies is must whenever we are going for any offshore investigation or any offshore errection the structures then second the offshore structure significantly larger than many of the onshore structures. The design level of the structures are in the range of 25 to 50 years, which is a different from the design life of onshore structure, like most of the structures particularly the oil Riggs are constructed even nowadays for the cases of bridges the most of the panels or parts of the actual structures are constructed on shore, brought to the actual site and are assembled, which is not done in particular in case of on shore. Then next one is ground improvement whenever we are requiring any kind of improvement most of the time it is not possible and if it is possible it will be very expensive because the environment in which we have to do improve ground improvement for this, lots of challenges to the actual execution of the work. Then lateral loads, either because of the winds or the water currents are significantly higher than in comparison to offshore structures, in comparison to onshore structure.

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Then exposed to large range of geohazards. Any offshore structure will be like Tsunami is there then water currents are there even whenever we are going for colder environments, like northern glacier most of the time in addition to water current, there will be impact through ice or glaciers that is another thing then Tsunami as I mentioned in earthquake is also there exposed to large amount of others. then ecological consideration should be given to importance important because of which though every location the location which are of continental margin but not everywhere people are going for exploration because of these restrictions. Then cyclic loadings are very dominating in comparison to onshore structures modifications, as I mentioned particularly during the module one when we go for onshore structure based subsurface exploration it is like one is for choosing the particular foundation, as well as in case you find any difficulty during laying the foundation you can think of alternate structures or alternate options but that modification particularly in case of offshore structure will be very difficult. Then if there is a failure in offshore structure you will have huge penalty in terms, of finance as well as in terms of environmental impact. So in order to get clearance first of all it is difficult and in case there is failures so that I can see the the factors on which time it will be there it will be significantly higher.

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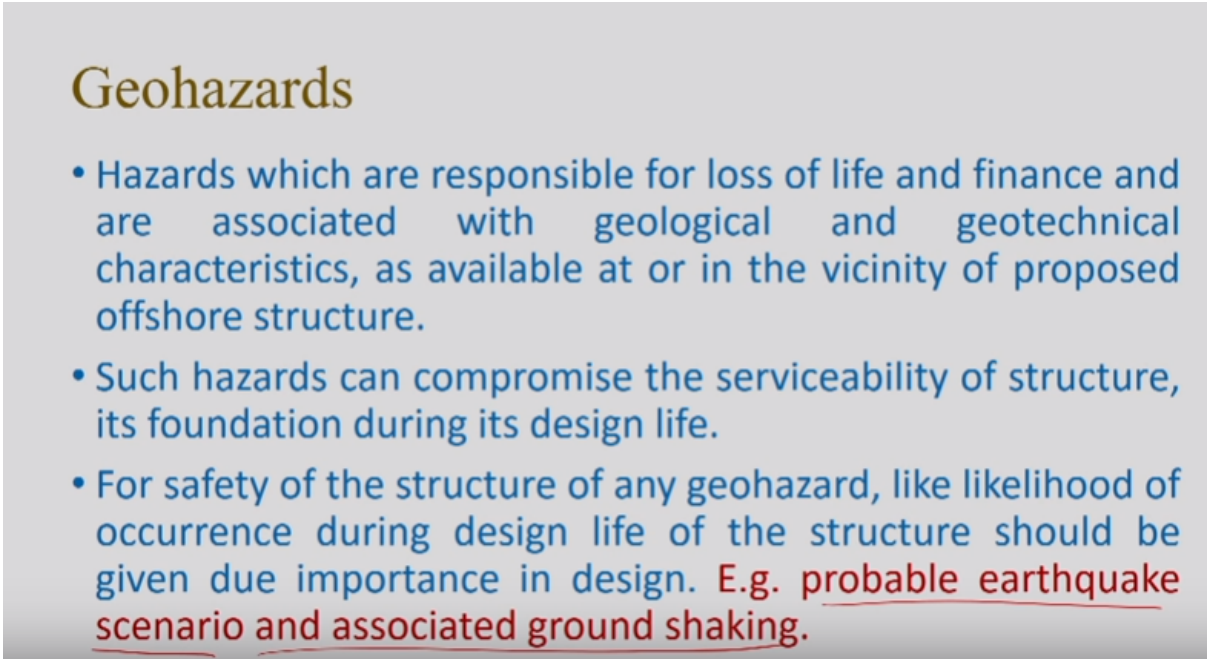

We mentioned about geohazards. So hazards which are responsible for the loss of life and finance and are particularly associate with geological and geotechnical characteristics of the particular site or its environment or its vicinity can be classified under Geohazards. Such hazards can compromise the serviceability of the structure of its foundation during its design life, so that is why geohazard should be given proper consideration, for the safety of any structure against geohazard we generally take into account, what is the likelihood of any particular geohazard it can be because of tsunami, it can be because of earthquake, it can be because of water currents also. So what is the likelihood for that particular geozard, to affect the structure and then accordingly the above factor should be given due importance in the design consideration and should be explored properly during exploration. To give you an example like probable earthquake scenario and its associated ground motion what will be the ground motion which is induced at the structure level or maybe at the base of the foundation and ocean floor interface that should be given to importance as a part of geohazard.

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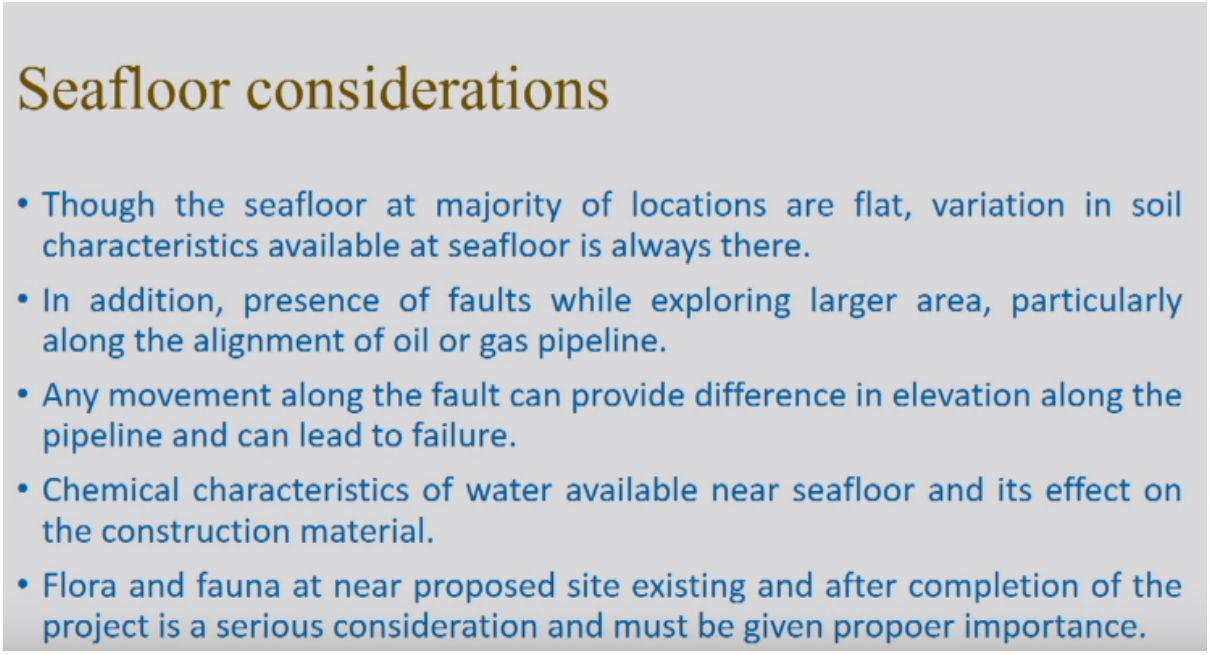

Now sea floor consideration, so this is very important here, though the seafloor at majority of location are flat, the trenches and seamounts which I told you those are available at specific location but not throughout, most of the time you find sea floors are very flat however they will be significant variation in the subsoil characteristics, available at the sea floor, so it will be wearing along the depth also, it will be varying latterly also. In addition if there is a presence of fault, which is a identified particularly when you are exploring very large area, along the alignment of gas or oil pipeline laying or may be transmission line cables laying, you have to also explore sea floor what are the possible faults which are coming along the alignment, what are the possible and there so that you are your mechanism for Anchorage should be designed properly that so that it can with stand that particular movement without compromising or without endangering the safety of the structure. Then chemical characteristics of the water keeps on changing with respect to the depth also, so what will be the change in the chemical characteristics upon the strength characteristics of the soil? because you are going to your home to investigate the soil but how that soil characteristics getting compromise with respect to the its environmental condition of chemical characteristics of water that you understand secondly the effective is chemical characteristics upon the foundation material the most important thing again and again the floor and the flora and fauna of the proposed site and its vicinity visible to get affected by the construction activity as well as the presence of a particular structure is to begin proper important.

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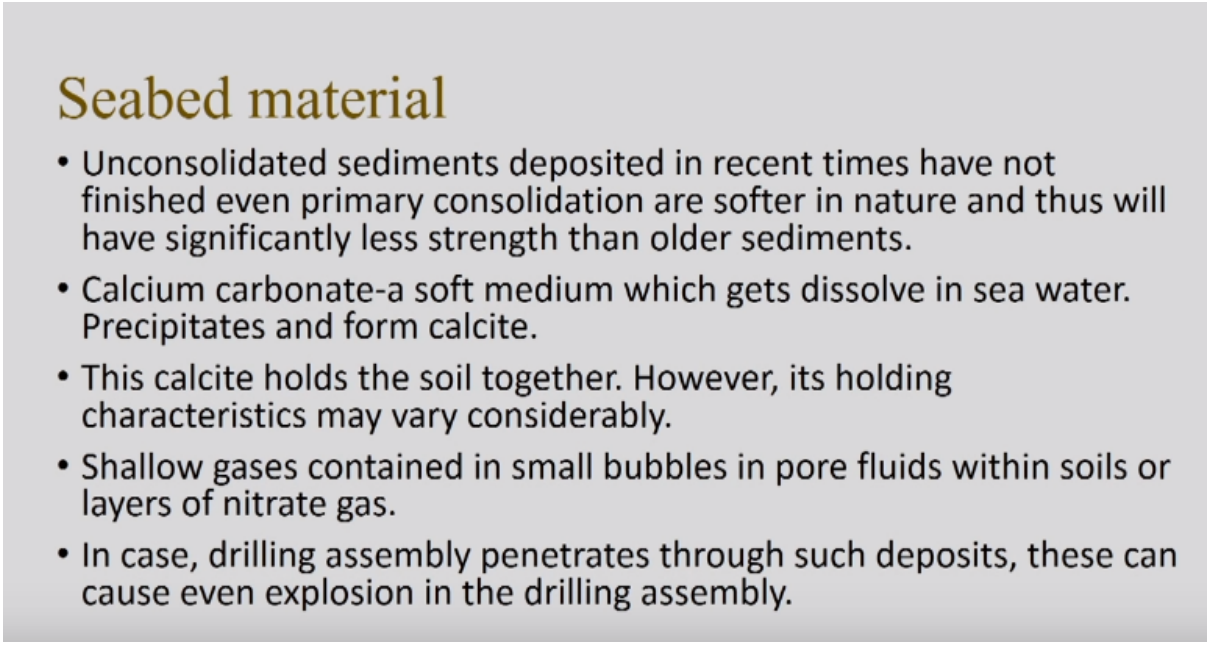

Now seabed material like we're discussing like it is changing but there are important consideration which has to be taken into, we should be given proper importance here include like the unconsolidated sediments which are often possibly available at the sea floor, so unconsolidated sediment means those are not giving proper time even to complete the primary consolidation social sediments will be softer in material softer in nature in comparison to the denser material, so that characteristic has to be understood while addressing the strength characteristic material. Calcium carbonate material which can easily gets dissolve in water and precipitates and from care side which is available abundant in the sea floor, particularly because of shells and other things, so once the organism dies, even that time also it get a precipitate from calcite, this calcite formed binds the software material of hard material together but depending upon the characters with calcite itself the binding characteristics of the and total will vary so that has to be given due importance. Third thing, like first one is like the settlement behaviour does the consolidation behaviour of medium, second thing is the binding characteristic of the calcite; Third thing is shallow gases which are present in form of small bubbles in pore fluids either within the soil pores, or in terms of gas nitrates in the solid layer. So once you start drilling what happened at times this bubbles comes out so so quickly it can even lead to explosion in the drilling assembly someone is telling assembly and second thing this these gases is nitrogen gas is very poisonous.

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- Further, gases coming out are highly poisonous and can even lead to death.
- Locations having such gas deposits are called "Sour gas Fields".
- Either such locations are avoided or proper preparedness is mandatory to avoid any accident.
- Sand dunes available are seafloor are under continuous process of movement due to deposition on one side and erosion of other side.
- Presence of sand dunes can bury the structure and can compromise its serviceability.
- A heavy sand dune can even induce settlement of the structure and thus should be given due importance while understanding the seafloor.
- Presence of hard sea bed can offer higher resistance against pile driving if required for the project and thus should be avoided.
- Hard medium in comparison to tough medium provides lesser grip or skin friction.

And it can also cause some kind of accident or it can cause even death also to the handling people, so we have to be very extra careful. Considering explosion point of view or considered a casualty point of view, in order to avoid any accident whenever we are exploring whenever you are going for any kind of detailed investigation this location, so those are called as 'Sour gas Fields', to be more careful and we have to be either we can avoid but majority of the location if we cannot avoid we have to be to be prepared for that, to handle that situation properly. Sand dunes as we know like there will be sand dunes which keeps on shifting because of erosion happening at other location removing the material and depositioning happening on others side of the sand dunes, so this process keeps on happening the sand dunes keeps on shifting may be slowly or may be quickly depending upon the rate of erosion or as well as the rate of the deposition, but what happen if the Sand dunes come above a particular existing foundation either they will buy the foundation or if the sand dunes are significantly heavier, it can induce settlement to the existing foundation and thus can compromise the safety of structures outside sometimes. Then another thing like the presence of bed, the bed is harder sometimes it gives you a challenge in going for pile foundation because it offers more and more resistance to wards driving. Another complication if you are going for hard bed it offers very limited resistance to as or skin friction shaft resistance. So in comparison to hard bed, tough beds are generally preferred and if it is not possible then you can go for may be suitable kind of pile foundation material. Today's class was more about how the ocean floors came into pictures, particularly referring to the continental drift theory, then what is happening at the interface, then where people started realising exploration of sea beds and important, when we go for sea beds it is not it is not very level one, sometime you have very much angulations, sometime you have trenches, sometime you have you have other characteristic. So the topographical features are varying significantly then has not got transmission boundary, you have where there are possibly higher chances of gas and oil storage, people started exploring and coming over to the recent demand, where people are going for artificial island, wind turbines, bridges, tunnels and storage is for carbon dioxide more and more applications of offshore structures are coming into picture which also allows whenever they going for any kind offshore structure as I mentioned earlier we have to go for detailed investigation so that the, so as to ensure the safety of the structure during

the design life as well as with minimal disturbance or no no disturbance to the flora and fauna Or ecology of the system so that the structure can be built as such into the proposed site as well as it is not it has minimal impact or nonimpact to its surrounding areas. So thank you so much. In the coming slides in the coming class we will be discussing these things in more details, how the exploration programmes can be planned? And typical examples of different exploration techniques. Thank you so much.