Geomorphology
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Lecture – 32
Coastal Geomorphology - I

So friends, good morning, welcome to this lecture series of geomorphology and today, we are going to discuss about the coastal geomorphology. So, see what does it mean, what is coastal geomorphology? If you confine yourself in coast in terms of geomorphology, there are 2 principal agents they work together; one is the wind or the Aeolian process as well as the marine waves, the tides, so all those indicates that mean how the coastal geomorphology will same.

So, out of that, the wind we have already discussed in arid zone geomorphology or the Aeolian processes and finally, we concluded that the wind mostly, responsible for formation of parabolic dunes and eolianite at the coastal regions and that is why we will confine ourselves in this work of the tide, the waves or the marine processes at the coastal plains or the coastal zones. Now the question arises; how important is it?

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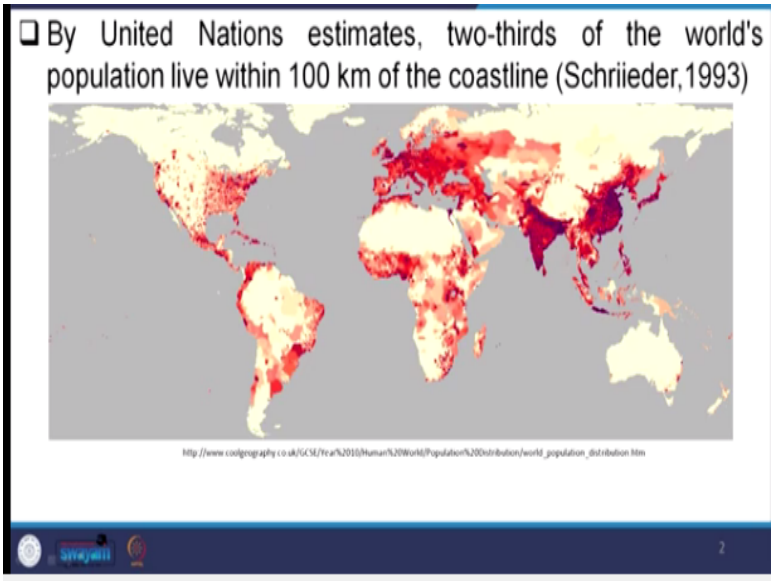

This coastal geomorphology, why we need to study the coastal geomorphology because there are certain estimations and it is presented to you here by the United Nations estimates, 2/3rd of the world's population live within 100 kilometre from the coastline. So, if you; our Indian context if

we see here, only except this Ganga plain, except those and all other the coastal plains, you see it is highly populated.

So, that means, any developmental projects mostly they are confined in the coastal plains, to see this populations, to mobilise this populations for the development of the society, we need to understand what are the coastal processes working, what is the geomorphic processes working along this coast, how they modify the coast and finally, to what extent this coastal that means encroachment or this marine transgression or marine regression that will affect our society, that will affect our developmental projects.

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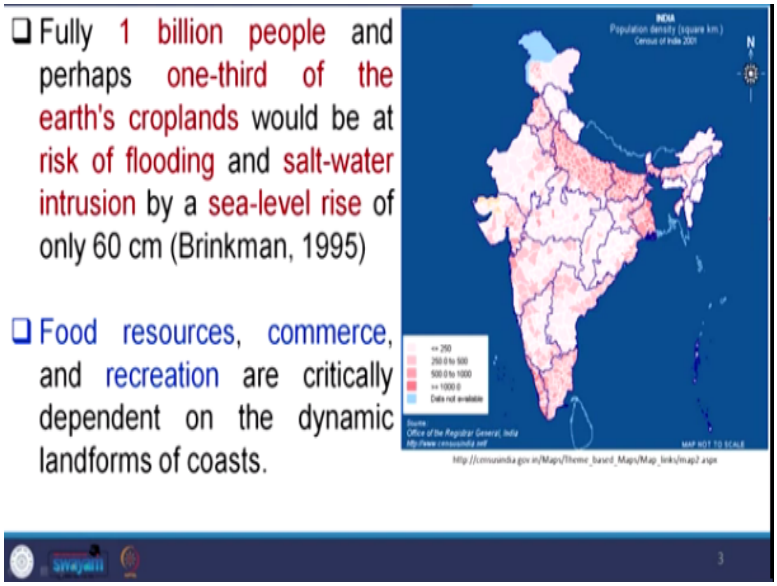

Fully 1 billion people and perhaps 1/3rd of this earth croplands would be at the risk of flooding and salt water intrusion by sea level rise, here you see there are 3 factors in a region; one is 1 billion people that means because we know that this coastal plain is totally highly populated and 1/3rd of the earth cropland that is important because cropland is very much important for us because for this cultivation purpose.

And if sea level rises that means, the marine water will enclose it and finally, whatever this cropland in the coastal area is totally be inundated and once there will be saltwater encroachment, there will be no chance of further salting because there will be salt within that soil. Second thing is that flooding; flooding once we have the increment of sea level, sea level

rises, so this water from these rivers that easily which has been transport to this marine level that will not be as easy.

So that is why this coastal plains that will affected by the severe flooding activity, then this sea level rise, once we say, sea level rise another term comes here that is called marine transgression and regression. So, sea level rise and marine transgression, they are 2 different things; sea level rise means, it is simply increment of water level or the mean sea level will rise up and whether this will enclose this land or it would not enclose the land, that depends upon the coastal condition there.

For example, suppose sea level is rising but the coast is subsiding, so that means, the rate of encroachment will be more and if the sea level is rising and this that means, the coast is also uplifting, so that does not mean, there will be marine transgression, instead there will be regression. Similarly, suppose, coastal plain is subsiding and the sea level are also falling, so that means but the rate of subsidence and the rate of falling is different.

Suppose, the rate of falling is more as compared to the rate of subsidence, so that means, there will be marine regression but if the rate of falling is less as compared to the coastal subsidence, so that there will be marine transgression, so that means marine transgression and sea level rise and fall or marine regression and transgression or sea level rise and fall, there are 2 different aspects, then what another factor is saltwater intrusion.

Saltwater intrusion nowadays, very highly alarming problem in this coastal areas because once we are increasing sea level, so that means we are increasing the water pressure and once water pressure increases at the sea, there will be a tendency to intrude into the coast or the coastal aquifers because by more and more population increment, we are extracting more and more ground water, so that this empty space is creating within that subsurface.

And once there is increase of sea level, there will be water pressure, water column pressure increase, so this sea water or the saltwater will intrude into this aquifers and this saltwater intrudes below the fresh water, so that means, once the sea level increases that will create severe

problem starting from inundation or this flooding problem that is; that means, intrusion of sea water, then encroachment of this coastal land, all those problem will arise with the sea level increase.

Then, food resource, commerce and recreations are critically dependent on the dynamic of the landforms of the coast. Food resource; there are 2 types; one is; our, this food which is created from the coastal cultivation, another is the sea food, second thing is the commerce mostly, the commerce that means, we use this sea water, this oceans as our; there is a commerce routes from one place to another place.

So, that is why that will affect, second this recreations; our whatever this developmental project we are creating in the coastal area and suppose, they are oil refineries and particularly, if we; Indian context if we consider, we have oil refineries, we have nuclear power plant and we have any things that means, any mega projects we have that is dockyard, so that means, there are mega projects, number of mega project they are concentrated or confined along the sea coast.

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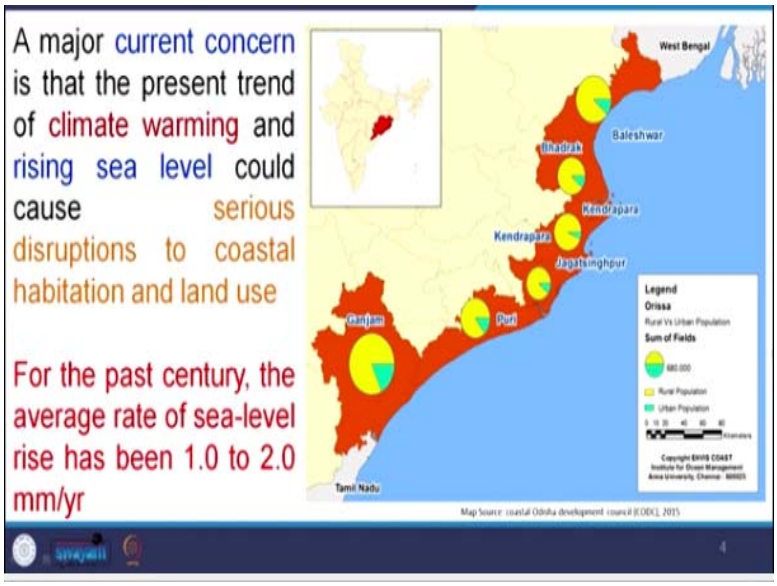

So, once the sea level increases that will definitely affect our systems, the major current concern is that the present trend of climate warming and rising sea level could cause serious disruption to the coastal habitation and land use, this is very important point to discuss here, this climate warming that means, we are going to an interglacial phase, if you see that in the quaternary, the

last 2.6 million years up to now, there are number of phases, the sea level has increased and decreased due to this climate change.

And this sea level decrease or increase that is created these many changes in our land use pattern, so for example if you see here in the Indian context we are confining here this part, this orange and this is the coastal districts or the coastal parts and if you see this population, mostly this population is; most population is concentrated in the coastal part and if these due to this climate change, the sea level rises and present day it is happening so.

Because if you have gone through this news that many of our Sundarban islands that has already been submerged, similarly at the present day, these sea level rise along the coast have been recorded to be 3 millimetre or 4 millimetre per year. So, if this is the rise of the sea level, then within 2040 or 2050, that many parts of this coastal land or the coastal habitats that will be submerged under sea.

So, this climate change it is contributing to this rise or fall of sea level, in the Pleistocene and the Holocene, when there were glaciations, so due to this glaciation, maximum water they were in the ice form, so that there are sea level that was decreased up to 100's of meter, so nowadays, if you imagine, suppose, the river which is falling its sediments here and sea level is decreasing up to 100 meter.

So that means, those rivers were debouching here that was deposited their sentiment at that level, so that is why there will be cutting of these river valley, there will be dissections of the river valley, river valley was more deeper than the present day, so due to the rise of the sea level now, the sea level is here and finally, the river has to deposit their sediments here, so that is why this paleogeography that was also controlled by the sea level rise and fall and this climate change.

For the past century, the average rate of sea level rise has been 1 to 2 millimetre per year, that 1 to 2 millimetre per year that is average but local factor is there, so that somewhere it is 1 millimetre to 2 millimetre somewhere it is more 2 or 3, 4, 5 millimetre, so that is why depending

upon the local factor, coastal encroachment or this marine transgression and marine regression will vary but sea level it is rising on an average of 2 millimetre per year.

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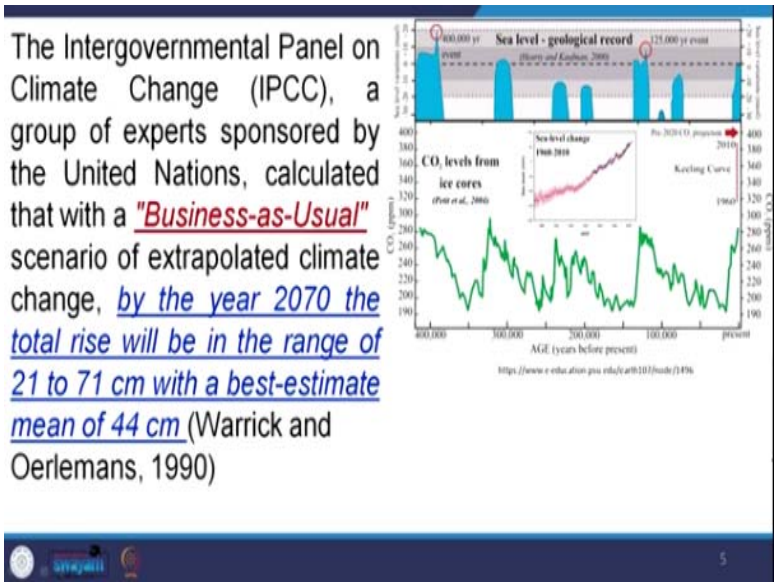

So, this intergovernmental panel on climate change, a group of expert sponsored by the United Nation calculated that with a business as usual scenario, the extrapolated climate change by the year of 2070, the total rise will be in the range of 21 to 71 centimetres with the best estimate mean of 44 centimetre. So, now you see here, if an average we are increasing by 2070, 44 centimetre that means, near about half feet, if you are increasing.

So, that means that half feet, it seems to be very less but it will affect tremendously to our programs, to our habitats, how? That half feet, I am sorry that 1 and 1/2 feet or the 44 centimetre that means, this marine water that will encroach up to this coastal land, the land largest and because our coastal plains they are very gentle slopes, this coastal plain particularly, the East coast of India, will be more affected than the West coast.

Because West coast it is steeply dipping western ghat is there, cliffs of western ghat is there but the east coast, it is totally plane area with negligible slope of 0, that means, 1 degree or less, so that means if that 1 and 1/2 feet is increasing, that will affect more area, that will submerged more area in the eastern part as compared to the western part and in the eastern part, we have

plains, we have crop lands, we have that business halves, we have that developmental projects, many of these developmental projects we are going to lose within 2070.

So that is why to prevent this, we cannot change the climate because though we say that it is climate change is a human created but the past geological history says, there was climate change. when there was no existence of human, so that means, it is a natural cycle, we have less control on that, though we are spending crores of rupees on that but hardly it will matter, so that is why we cannot change the; we cannot stop this climate change.

It is a natural cycle it has to occur, so that thing is that we have to prevent; we have to prevent our own business, we have to prevent our own infrastructure, so that is why we have to prepare, we have to plan like that, what type of structure we are going to build or what type of changes in our land use we are going to create, so that it will be least affect by these rise of sea level. So, that is why to construct this infrastructure, to align those infrastructures, to build where this infrastructure will be build, what type of infrastructure we need to prevent this type of changes.

So, that means we need to understand what was the coastal processes, where, which part of the coast, what type of coastal processes is; some where it is tide dominated, somewhere it is wave dominated or somewhere it is an estuarine, somewhere it is a cliff, somewhere it is a plane, so that means, depending upon the change in geography, depending on the change in the geomorphology, so there are different dominance of factors that is working.

So that means, we have to understand those dominances, those factors which are dominating acting in a particular area, so that we have to modify our developmental program, we have to modify our this infrastructural developments, so that it will least affect by this increment of this sea level.

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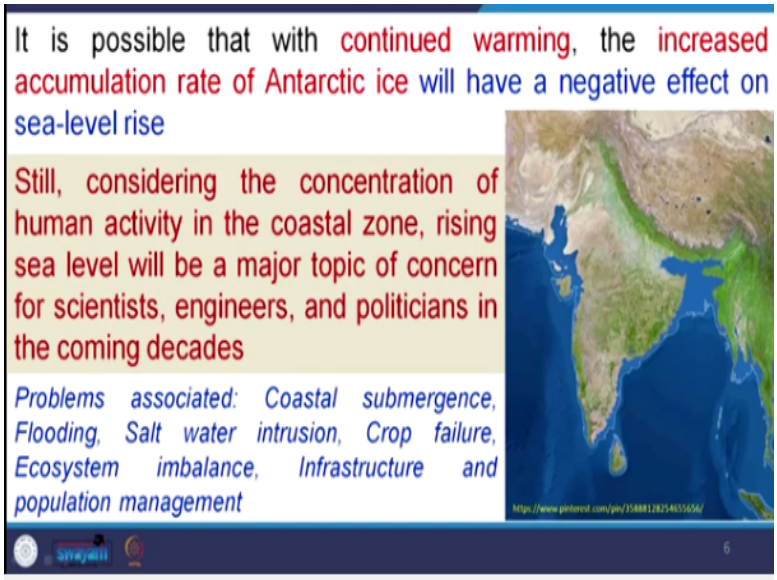

It is possible that with continued warming, the increase accumulation of rate of Antarctic ice will have negative effect on the sea level rise. So, if you see here, this is in a figure which is future; projected for the future, maximum part of this Indian coast, east coast particularly, if you see east coast, the this part is totally submerged and this Ganga delta or the Ganga plain, half part of this Ganga plain is totally submerged.

But as compared to the west coast you see, west coast is less affected and maximum affect will be in Gujarat, Rajasthan or so, that is why if this type of climate change will continue, so there will be decrease in ice sheet, the ice volume in Antarctic and Arctic region that will contribute to the rise of sea level and those rise of sea level will submerge maximum part of this usable lands on the earth crust.

Still, considering the concentration of human activity in the coastal zone, rising sea level will be a major topic of concern for scientist, engineers, politicians in the coming decades, so here we need to modify our policies; policies in terms of that means, that is administrative policy, policy in terms of scientific policy, in engineering policy, so to tackle this type of a problem, we have to modify our policies so.

Problems associated is the coastal submergence, coast will submerge, then flooding as we have discussed that once the sea level rises, this river water will not easily go to the sea level, so that

sea level rise is a problem and flooding will be another problem that will be add to it, then saltwater intrusion, once we are increasing the water level, we are increasing these pressure; water column pressure, so that this will be easy for the seawater to intrude into the fresh water.

So that means, we will be getting difficultly to get into to find this drinking water, then crop failure, yes, because the coastal plains mostly, this land is or they are very fertile and once there will be sea level rise and once there will be a flooding, so maximum land will be covered with water, sometimes somewhere it is will be covered with the flood water, so that means, we will have crop failure.

Then, ecosystem imbalance yes, once there will be somewhere, maximum land will be submerged under sea, so whatever this balance has been developed by the ecosystem, that will be breached and finally, there will be ecosystem imbalance, then infrastructure and population management, this is very important. The infrastructure and population management because you see, 60% of our human population they are concentrated at the coastal plains.

Now, once the coastal plain will be submerged, that 60% has to be; have to be that means, replaced from there and will be distributed along these land area, so that means, this will be the severe problem, infrastructure and population management. So, if you see here this figure representing this Indian east coast or particular Orissa coast, you see there are few dashed line, those dashed line they represent, the paleo coast position or paleo sea level positions.

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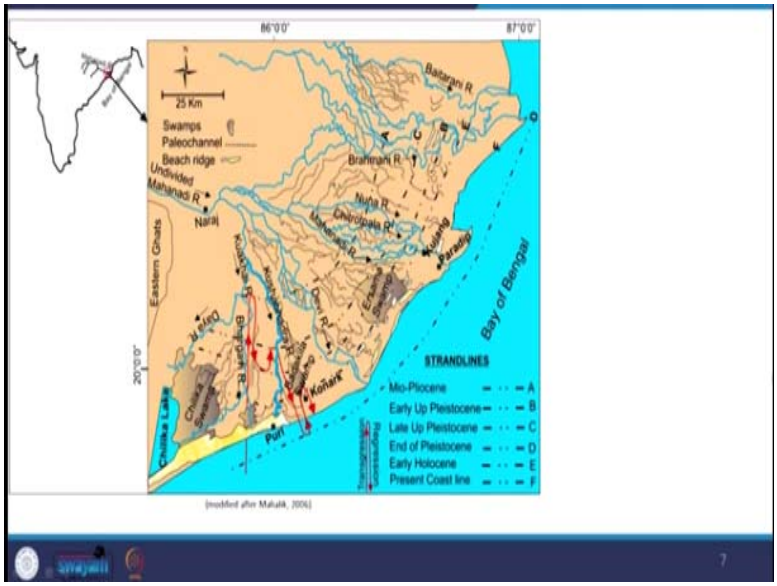

Here you see, if this is the present day coast and from this geological past, it is from this; this is from early Pleistocene to early Holocene, A, B, C, D, E which is represented by these letters, if you see earlier, this was the coast and finally, it was here and gradually, it decreased up to this level, then it decreased to this level, then it is increased, then it is sudden decrease up to this, then it is increase now, it is decreasing and finally, it is increasing.

So, that means, it is not the present day problem or it is happening in the present day only, in the geological past from millions of years, there are cycles of sea level rise and falls, so those sea level rise and falls, they submerged some area from the land and they immerge due to sea level falling. So, this problem persists from the geological past not the present day problem but the problem or the concern is here.

We have to modify ourselves, we have to modify our land use development, we have to modify our coastal management, so that means, this problem will be there, there will be no doubt, so how this problem will less effect to the human population, less effect our land use pattern, less effect our infrastructure that we have to plan. So, for planning this, we have to understand properly how the coastal processes work.

And which part of the coast is affected by which type of process, so that we can modify our developmental project, we can modify our land use project, we can plan for the future to tackle this problem.

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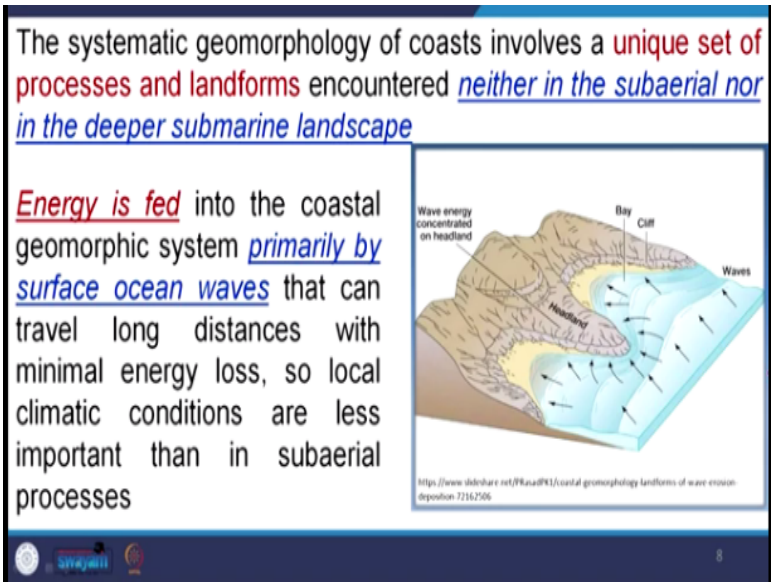

The systematic geomorphology of coasts involves a unique set of processes and land forms encountered neither in the sub aerial nor the deeper submarine landscapes. So, here we are talking about the coast, so coast is a transition; is a transition between this land surface and the marine process, so it is away from the deep marine process, you can away, that means, if we confine ourselves within the marine, there will be shallow marine process, we have continental shelf.

Then, we have continental slopes, then continental rise and the deep ocean floor, so that means the deep ocean floor, the process is different, at the shallow marine positions, shallow marine and continental shelf, the process is different similarly, in the lands surface, this process is different, so this coast it is fluctuating, it is here and there, this to and fro it is fluctuating due to the sea level rise and falls and this is a transition.

So, that means it will partly affected by this land surface processes and will partly affected by the marine processes, so that means here 2 process has to be understood properly to align ourselves with the change, so energy in this coastal region is fed into the coastal geomorphic system

primarily by surface ocean wave, so ocean wave is the primary energising agent here, so this waves it is moving that means, to and fro and finally, it is dissipating the energy; the wave energy into tides, into the; in to distributing among the sediment particles to move.

So that means, wave energy is the main source of energy to modify the coastal system but that is not true always, some of this coast they are dominated by waves, at some part of this coast, that is dominated by tides, so that means, depending upon the dominance, which area is tide dominant, which area is wave dominated, so that the land forms are developed also accordingly, the erosional process also occurs accordingly.

The depositional process occurs accordingly, so that is why we have to divide or we have to make it as different segments, which part of this coast is dominated by what type of energies, so driven by surface waves, the energy is fed with the coastal system that can travel to long distance, with minimal energy loss, so local climatic condition are less important than the sub aerial processes here, those wave energy that is generated from somewhere else within the sea.

And that wave energy is transferring, it is coming to a long distance without loss of energy and finally, that energy is dissipated along this coast through the sediments through erosion or through depositions, so that energy, how much energy is concentrated which segment of this coast that has to be worked out.

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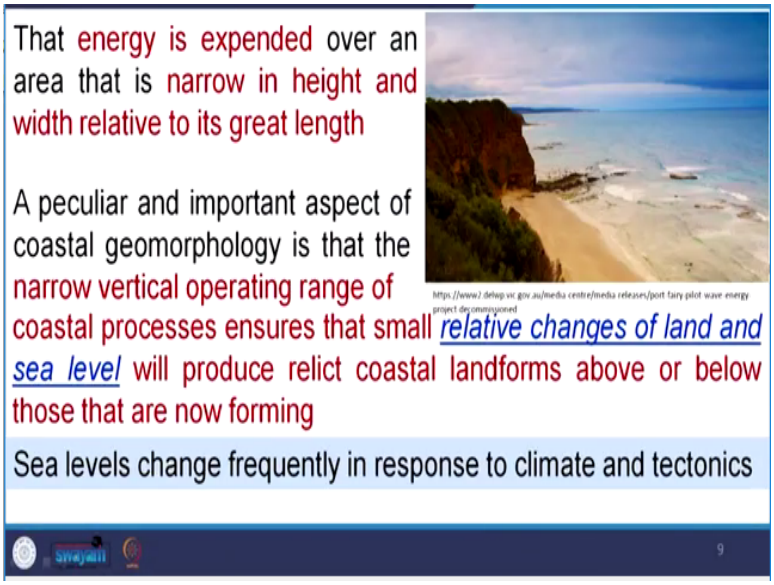

That energy is expended over an area that is in narrow in height and width relative to its greater length, if you see here, this is the whole coastal region and it is the open sea is here, so here from somewhere if the next level it is that wave is formed and finally, the wave is transferring to the coast and finally, it is dissipating that. A peculiar and important aspect of coastal geomorphology that the narrow vertical operating range of the coastal processes ensures that small relatively changes in the land and sea level which produce relict coastal landforms above or below those that are now forming.

So here, very important to understand here that is relative change of land and sea level will produce relict coastal land forms that above or below those that are forming now, so for example suppose, we have present day coast, that means, present day coastline which is separating the land surface to the marine surface. Now, any small changes; any small change in the sea level, any small shift or they relatively very meters of centimetres shift of this, that is coastline that will affect a large to this depositional system, to erosional system.

That means, those agents which are working at the coastal land forms, those land forms which are being created at the present time that will affected by the change of the sea level, so in the geological past, when the marine level or the sea level was 100 meters or 50 meters or anything which was below this present day, so that means it is creating a huge accommodation space.

And that accommodation space was modified or filled or somewhere it is removed by this depositional agents or other geomorphic agents, so that means I want to say, any small change in the sea level that will affect large to this land form developmental process. Sea level change frequently in response to climate and tectonics, here another culprit is added is tectonic. Climate that means, only the aridity and the humidity that does not change the sea level, there is tectonics.

Tectonic equally responsible for this change of the sea level, for example, you might have heard about the eustatic sea level changes; eustatic sea level changes means, a sea level which is measure from the centre of the earth, so eustatic static sea level changes, most eustatic sea level changes occur during this development of this mid oceanic ridge, so mid oceanic ridge when huge basalt comes out along this mid oceanic ridge system, it will expand the water, it will swell this water level.

So, that the marine level or the sea level will be increase, so that means, similarly, in the Indian east coast, if you confine yourself, you will find, there are number of parallel faults, basement faults, they are parallel to the present day coast. For example, basement faults, some of the faults are active and were loading with sediments, so that the whole system will subside, once the whole systems subsides, so that means, there will be change of sea level, local change of sea level.

This is not eustatic sea level changes, eustatic sea level changes, they occur worldwide that is measured from the centre of earth to the sea level but here it is local sea level changes, so that means, tectonics; it is changing the sea level locally as well as globally, so that along with the climate change, this tectonics plays another important role for changing the sea level.

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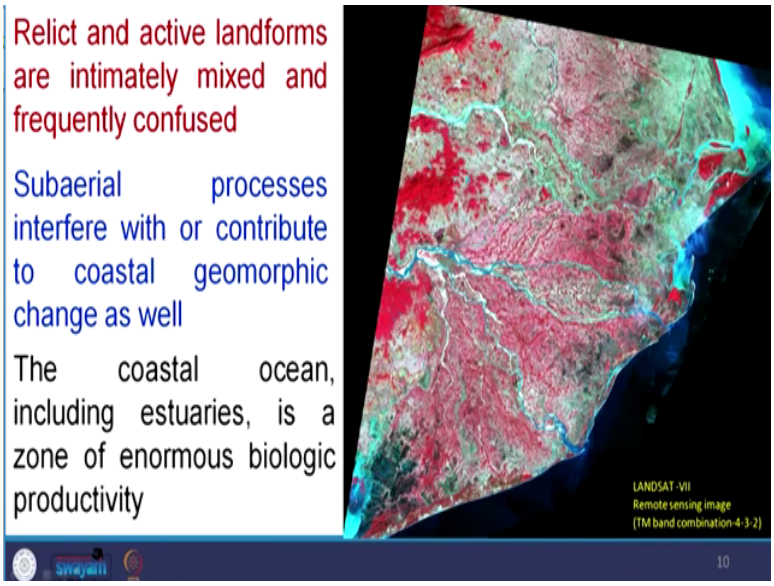

Relict and active landforms are intimately mixed and frequently confused for example, if you see here this is the satellite imagery of Indian East coast and part of the Orissa coast it seem, you see this is the present day sea level and this is a wave dominated coast, where this landforms if you see, they are forming parallel to the coast and these are this land forms, these are the linear land forms if you see here.

These are the relict landforms, they representing the sea level at the geological past, so that means, relict and active landforms; relict land forms are there which is representing the ancient sea levels, the geological past sea levels and the active landforms present they are forming, so that will be confused, we have to distinguish which one is the present day one and which one is the relict one.

Then sub aerial processes interfere with or contribute to the coasters geomorphic changes as well, sub aerial processes; sub aerial processes here is wind processes, this river processes, they also affect the coastal geomorphology because for example, if you see here in this satellite imagery, this is Mahanadi delta and in Mahanadi delta, you see these are this branches of this Mahanadi in different names.

They are dividing the delta into different domains, now here if you see where this meeting this coast, this coast is wave dominated however, particularly those area which were rivers are

debouching their sentiment, they will be tide dominated, so that means, this sub aerial change also, sub aerial process also that affect the coastal process to certain extent. The coastal ocean including estuaries is a zone of enormous biological productivity.

This biological productivity that is the photic zone of the sea floor and this transition, this river, this estuaries, those are these areas were this biological productivity is more that is why if you compare the present day system with the past geological system, many of this hydrocarbon deposits they are concentrated in the shallow waters; why shallow water; because this if we believe that the petroleum hydrocarbon is a product of organic matters.

So, many or these most of this organic matters, they are concentrated near to the coast in the continental shelf zone, the estuary zone in the river dominated part, so that is why most of these sediments or most of these biogenic sediments, they are confined in the coastal part and that the estuarian parts or this deltaic parts So, that is why we have river systems that is affecting this coastal processes that means, anything which is happening in this sub aerial process that is transformed or transported through the river to the coast and modifying the coastal process also.

So, that is why the coastal process is not only the wave dominated system or the marine dominated system, it is a transition between this sub aerial system and the deep marine system, so this coastal process has to be understood properly, which part of the coast is dominated by which type of the system, is not it. So, I think we should stop here, thank you very much, we will continue in the next class, thank you.