Mineral Resources: Geology, Exploration, Economics and Environment
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Lecture – 36
Mineral Exploration (Contd.)

Welcome, to the lecture of this series and this week's lecture. In the previous week we got ourselves introduced to Mineral Exploration with an overview of classification, economic classification of mineral resources and with the concept at the back of our mind exactly what we are going to explore what we are looking for and mostly we will be restricting ourselves to the discussion on these scientific aspects of mineral exploration.

And the science that all that we have acquired got an overview of the processes that form mineral deposits and we will see how effectively we will be in a position to utilize that knowledge to develop the methodologies or to see them and how the methodology actually worked by using principles using the scientific principles that we learnt about mineral deposit formation in general.

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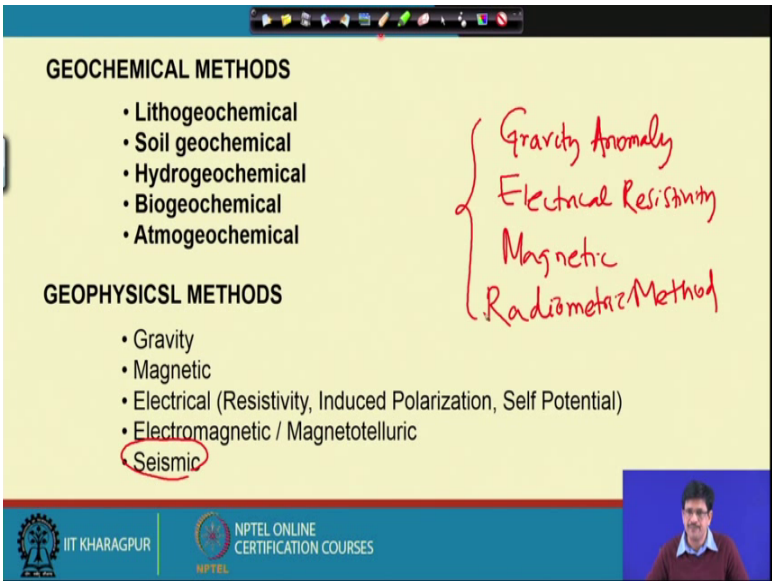

The last week we just began our discussion and we also discussed that the it is geological method which lies at the core of the activities and we use the fundamental knowledge on the geochemical characteristics of a metals, elements, their mobility in the primary and the secondary geochemical cycles and use those principles to identify or to detect the presence of mineral deposits which are hidden below the surface by bringing up or by coming out with something which we call as geochemical anomaly and the geochemical anomaly as we discussed could be of various nature and dimension and magnitude coming from the coming a signatures of hidden mineral deposits below the surface and they need to be very carefully interpreted it is the there are lots of intricacies involved which we discussed a little bit about them.

And, the geochemical methods that we use can be broadly a litho geochemical when we take the samples of the rocks which are exposed on the surface and when we suspect that there is some mineral deposit which is present below the surface then we sample the rocks, the sampling strategy being decided by our background geological knowledge and the overall geological setting, the rock types and from which we built up or redeveloped the idea and through our reconnaissance and detailed survey stages we wanted we intend to delineate the ore body and use geochemical methods.

If the area is soil covered, then we sample the soil if there are some water bodies stagnant surface water bodies or groundwater which is sub surface which are circulating ground water through rock formations which are water bearing or rock formations or we can also analyze the plants which grow on the soil the soils being overburden to a mineral deposit which is lying below and sometimes we also use the method of analyzing the rare gases in the atmosphere and sample them and also can go about our exploration for hidden mineral deposits of specific types like, for example the uranium deposits.

And, we also do take help of the geophysical methods and we do not have the scope of getting into the details of these methods because they need very elaborate understanding on the physical principles which is beyond this scope of this lecture series, but what we can do, we can just see how these methods without getting into their much of details in terms of the interpretation of data or the detailed mathematical treatment that is done to the geophysical data that are required.

We can see some case studies where such methods have been utilized. As I have stated before a successful discovery of a mineral deposit is after is an outcome of utilization of all the techniques and synthesis of all the information together which will be we generally work in reinforcing each other and to finally, get a confirmation or get a idea get an idea about the presence or absence of a mineral deposit which is below the surface.

So, when it comes to a situation like gravity, that means, we are actually using the fundamental physical property, contrast in the physical property between our suspected ore body and the surrounding rock. Gravity is an essentially will be if we take the normal situation where there are crustal rocks the gravity signature that we get is a background signature or a normal original signature which we get and if we if there is a body say for example, there is a this kind of things could be very well depicted.

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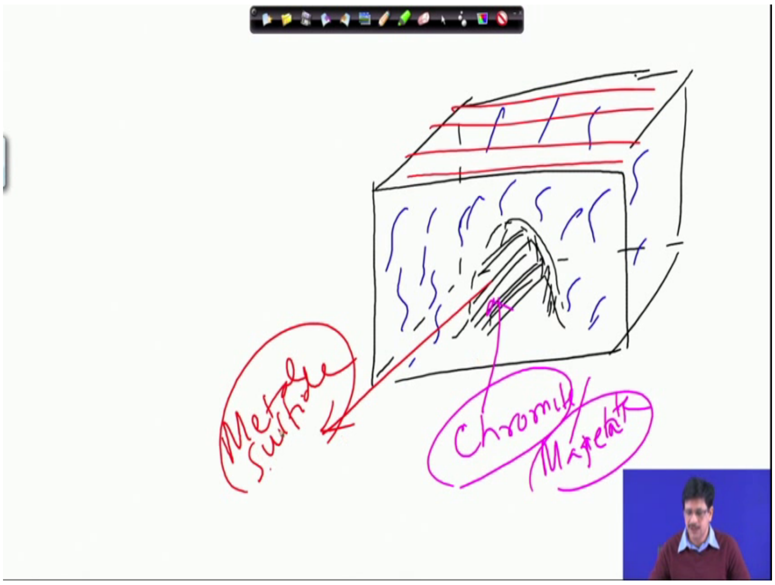

Essentially, what I am representing here is a part somewhere anywhere in the crust where it is a normal crustal rocks silicate rocks let us consider this a nysic rock or a felsic rock or some kind of a better sediments or quartz felsmethic nice country rock and in which we have a body of an ore which is a concealed below the surface.

So, fundamentally suppose let us consider that this happens to be an ore body of chromite or say or magnetite. So, if it happens to be a body of chromite then this body of chromite is likely to have a distinctly different density and the then the rock which are surrounding this body and if we take the gravity field or the gravity field of this area then we definitely going to get some signature which will be indicating that there is some body which is present there by virtue of its higher specific gravity higher density. It is creating in an anomalous area which can be detected if we do a gravity survey in the area.

Say, if it happens to be a body of magnetite then it is like this body of magnetite by virtue of it is higher magnetic susceptibility will also cause the local magnetic field which can be measured by a magnetometer. There are various components that we measure here and we take something which is called a magnetic anomaly and we present them whether it is a gravity or it is magnetic property then we present the data the result in the form of the anomaly in map.

And contouring them on this surface on a 2 dimensional or 3 dimensional view and suspect the presence of such kind of a body which by virtue of its difference in the physical property like a magnetic property or the specific gravity or even, say for example, if this ore body that we are showing here is a body of sulfide is a metal sulfide; this metal sulfide body by will have a higher electrical conductivity compared to the surrounding rocks.

So, if we take a measurement on the electrical conductivity or what exactly we measure which is essentially the resistivity which is inverse of conductivity of the rock mass over here and take traverses and different such kind of traverses we take then by virtue of the difference in the electrical conductivity of the ore body with respect to the surrounding rock it is going to give us some signal in the form of a lower resistivity body which is present in the sound in the surrounding of the normal country rock.

So, here we are essentially using our basic principles of the electrical methods of prospecting or a magnetic methods of prospecting or a gravity method of prospecting and these are the basic difference in the physical property of the ore bodies and when we are discussing with a simple diagram we presenting a case where we start with a very simple shape of the ore body.

And in nature the shape of the ore body could be at an any complicated geometry and the kind of anomaly what we are calling as either it is a gravity anomaly or an anomaly which is detected by electrical resistivity or the magnetic or detecting a magnetic anomaly or a an electromagnetic which is another method which also depending on the property of the ore body we can also use a method which is an electromagnetic method.

And, we also use the seismic method where the seismic method initially, essentially, is used taking help of the difference in the way the elastic waves propagate to the rocks and they are more effectively utilized for hydrocarbon resources like petroleum and natural gas, but often or very infrequently used for exploration of metal metallic deposits either oxide or sulfide deposits.

And, so, we can also have the radiometric methods by which we measure the radioactive waves which are generating from the radioactive decay of parent radionuclide like uranium, thorium and such deposits when they concealed below the surface where the earth and they generally give a higher than background value of such intensity of these electromagnetic waves which is essentially the gamma rate which have a better penetration and measurable by using appropriate device.

So, all these methods that we employ for the geophysical methods of exploration or even we can call prospecting they use sophisticated instrumentation and in these field only. The development has been quite significant in terms of the methodology used for reduction of the data and now, there are often what is used as combination of more than one technique and join many of the data are combinedly used for a better interpretation and more dependable interpretation for detection of hidden ore bodies.

And as I have said that a successful discovery of a mineral deposit eventually, would have used the both geochemical and geophysical methods and all the results when they are compiled or synthesized together, then only the final result in terms of the inference on whether a deposit exists or not is actually made after the complete evaluation or all the data that is generated at these methods.

So, we will not be getting into all the very fundamental principles with their equations with their or even the working principles of these things like a gravimeter or the proton precision magnetometer or in the gamma spectrometer things like that or even there is instruments like seismograph which detects the seismic waves that are generated by some artificial means in the process of mineral exploration.

So, with this much of background information, we will be dealing with the discovery of some selected deposit types and also we will see the general methodology that could be applicable in general for resolution of some specific type of deposits and as I have stated before mineral exploration today, is essentially targeted towards specific deposit types of specific metals and the exploration program is so designed so that it takes into account those identified geological elements which are to be specifically looked for during the process or during exploration of such deposits.

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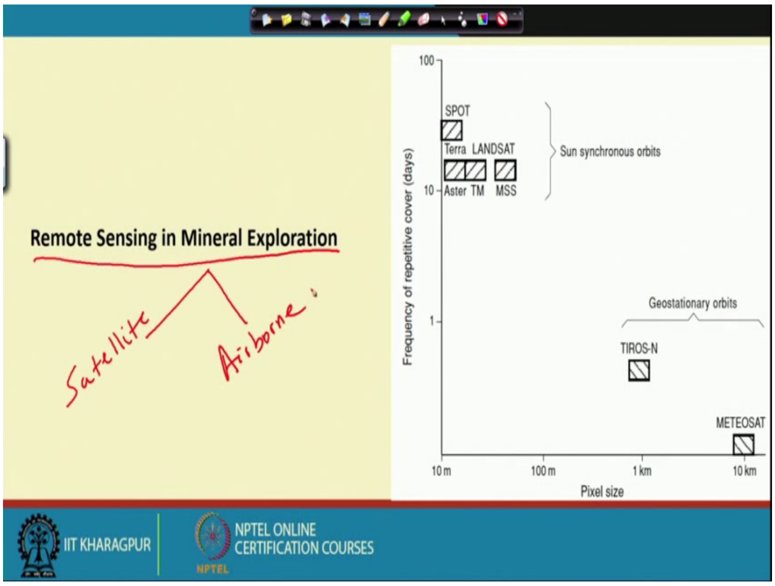

With that little bit of a brief introduction of the this exploration methods that is employed we will try to have a bit of an overview general idea about a very widely used methodology of the present day that is the remote sensing in mineral exploration. If we even start from the re-standard definition what remote sensing is that we make impressions or idea or estimation about any object or by examining it from a remote distance.

So, the remote sensing generally could be done by a satellite which can be put into an orbit as hundreds of kilometers above the earth surface or it could be airborne. We saw some of the points that we do have many such airborne exploration methods airborne magnetic method, airborne gravity survey where we generate gravity anomaly or magnetic anomaly of large regions which can be used during the reconnaissance survey and similarly, the remote sensing work can also be carried out by taking the instruments which are our spectrometers in aircrafts which will be only within about a few thousand meters from the surface of the earth.

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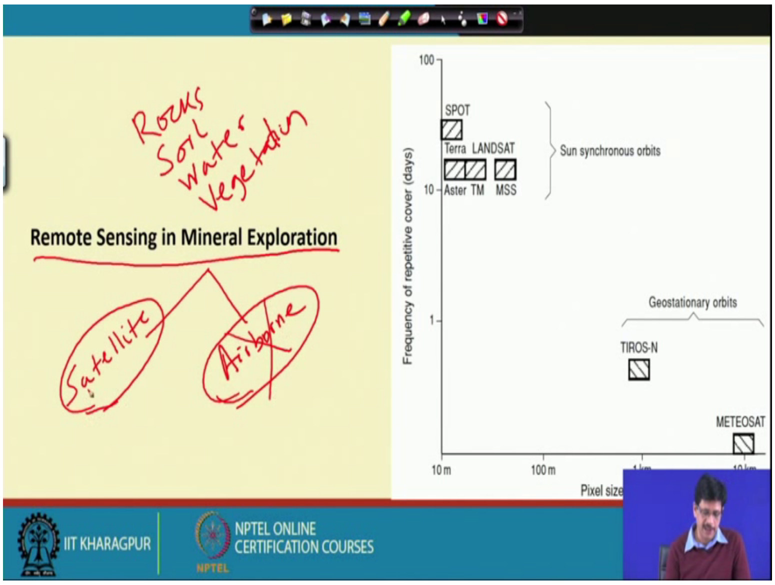

And, the kind of maps that they will be generated by airborne methods will usually have a larger bit larger scale than that of the satellite. Satellites, because these are placed hundreds of kilometers above the surface of the earth and they are the advantage is that we can get a synoptic view of the earth surface and could examine the earth objects. The earth objects will be the rocks, soil, water and vegetation.

So, in this short discussion that we will have on this remote sensing method we will not consider the airborne methods which were initially were called as aerial photographs which will not be discussing and these days even there are airborne spectral radiometers which also take the deflection from the earth surface on the in the electromagnetic waves. So, we will not be considering the airborne method will be only be discussing the satellite remote sensing method.

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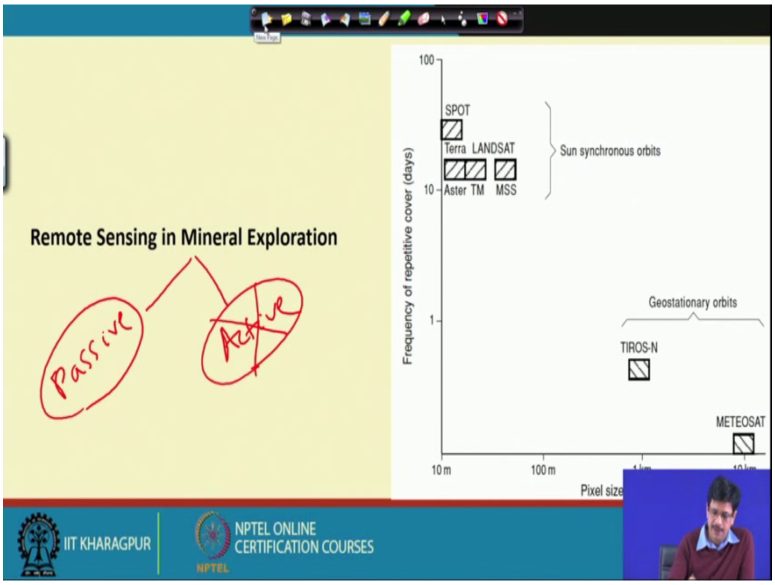

So, as we know this satellite remote sensing that is done is essentially could be of two that is the passive remote sensing and active remote sensing. So, passive remote sensing is the one in which we use the suns electromagnetic energy for our use. In case of active remote sensing, we generate our own electromagnetic wave of a desired wavelength for very specific purposes and we will not be discussing on this active remote sensing.

Mostly, we focusing on the methods which are essentially passive remote sensing where we are using the suns electromagnetic radiation that is interacting on the earth objects and the resultant waves that are reflected as well as emitted from the earth's surface analyzing them and making meaningful interpretation about earth objects specifically to see how they will be helpful in mineral exploration.

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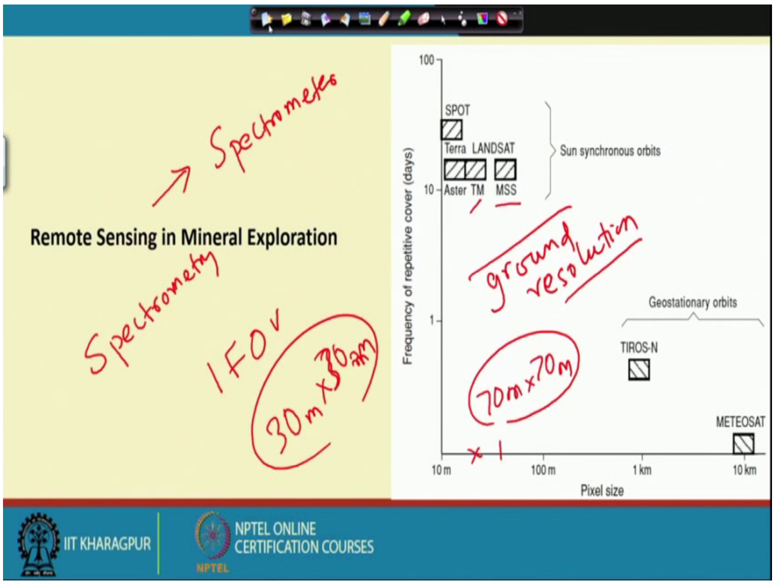

So, essentially we can call that this remote sensing is nothing, but a spectrometry in the largest possible dimension. When we are taking the earth surface which is taking a view of several hundreds of square kilometer area of the earth surface at any one point of time and receiving the reflected or emitted electromagnetic spectrum in this entire wavelength and that is coming from the different earth objects as we say rocks soils water and vegetation.

So, coming to the very fundamental ideas about the remote sensing; the remote sensing essentially are what we understand the camera on the that is mounted on a satellite is essentially a spectrometer, that is, designed to receive the electromagnetic radiation in specific wavelength intervals and that is how and the data are recorded in the in digital form and are subjected to very elaborate exercise of digital image processing which will not be discussing in details in this lecture, they are a specialized topic of digital image processing of remote sensing which could be taught separately, but here we will only be concerned about the application to remote sensing here on this diagram it gives us an idea.

So, this remote sensing satellites are they were launched way back in the mid 70's starting from the LANDSAT series, the MSS is the Multispectral Scanner and the TM is the Thematic Mapper, Aster is the advanced space borne thermal emission of radiation radiometry and SPOT is a French satellite. So, these are the ones which are the sun synchronous satellites which are designed for acquiring the digital image the acquiring the image information, image in the electromagnetic in the radiation and will be stored in digital form which can be processed to give the satellite image it is what we examine.

So, considering the sun, here we could see the ranges. So, here on the x axis is a pixel size which is given in meter kilometer and we could see that satellite camera like spectrometer like a multispectral scanner having some kind of around 70 meter by 70 meter of the pixel size or what is basically essentially known as the Instantaneous Field Of View – IFOV, and this multispectral scanner and then the Thematic Mapper. Thematic Mapper had a little even smaller the area, about 30 meters Thematic Mapper is somewhere here. Thematic Mapper was kind mostly 30 meters by 30 meter area as the instantaneous field of view.

So, the utility or the usefulness of the satellite camera is essentially dependent on these two parameter and it gives the frequency of repetitive cover per day, so that any part of the earth surface could be repetitively studied to take care of any of the transient phenomena like cloud cover and many other things and, here these satellites as we will see them later. So, the utility of those satellites will be depending on what the pixel is or which we can call as the ground resolution.

So, smaller is the ground resolution a better the satellite imagery is, because we could study features which could be of much smaller dimension; for example, if any earth features like a like a mineralized vein which measures only in a few tens of meters may not be possible to be studied by a satellite imagery where the ground resolution is 70 meter to 70 meter.

Whereas, so, that means, the better and better the ground resolution better it is useful for mineral exploration purpose and. So, these are the say the mss the multispectral scanner was sometime in the mid 70's was launched by the name NASA and it was followed later on by the satellite spectrometers which were improved and in what way we can just see because the other aspect of a satellite imagery is that in what spectral range this particular spectrometer has been processing the electromagnetic the range of the electron the wavelength of the electromagnetic spectrum and in how many for in what intervals or what window.

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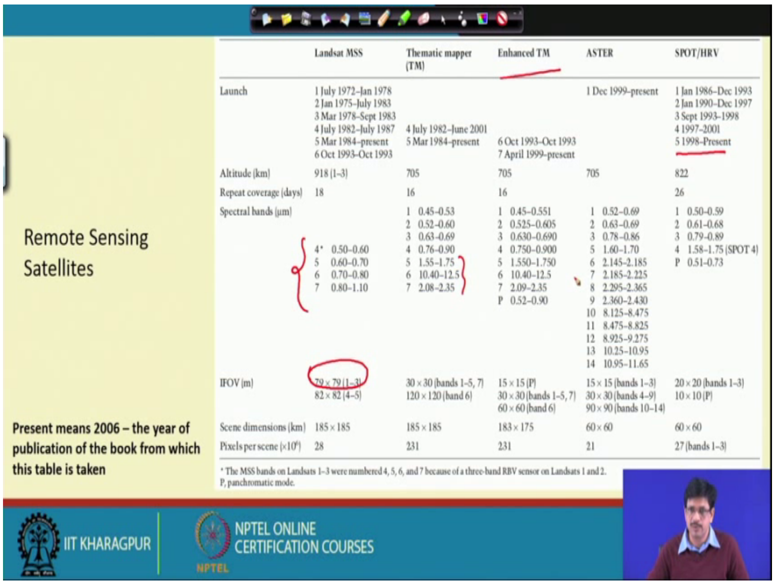

	Landsat MSS	Thematic mapper (TM)	Enhanced TM	ASTER	SPOT/HRV
Launch	1 July 1972–Jan 1978 2 Jan 1975–July 1983 3 Mar 1978–Sept 1983 4 July 1982–July 1987 5 Mar 1984–present 6 Oct 1993–Oct 1993	4 July 1982–June 2001 5 Mar 1984–present	6 Oct 1993–Oct 1993 7 April 1999–present	1 Dec 1999–present	1 Jan 1986–Dec 1993 2 Jan 1990–Dec 1997 3 Sept 1993–1998 4 1997–2001 5 1998–Present
Altitude (km)	918 (1–3)	705	705	705	822
Repeat coverage (days)	18	16	16		26
Spectral bands (μm)	4* 0.50–0.60 5 0.60–0.70 6 0.70–0.80 7 0.80–1.10	1 0.45–0.53 2 0.52–0.60 3 0.63–0.69 4 0.76–0.90 5 1.55–1.75 6 10.40–12.5 7 2.08–2.35	1 0.45–0.551 2 0.525–0.605 3 0.630–0.690 4 0.750–0.900 5 1.550–1.750 6 10.40–12.5 7 2.09–2.35 P 0.52–0.90	1 0.52–0.69 2 0.63–0.69 3 0.78–0.86 5 1.60–1.70 6 2.145–2.185 7 2.185–2.225 8 2.295–2.365 9 2.360–2.430 10 8.125–8.475 11 8.475–8.825 12 8.925–9.275 13 10.25–10.95 14 10.95–11.65	1 0.50–0.59 2 0.61–0.68 3 0.79–0.89 4 1.58–1.75 (SPOT 4) P 0.51–0.73
IFOV (m)	79 × 79 (1–3) 82 × 82 (4–5)	30 × 30 (bands 1–5, 7) 120 × 120 (band 6)	15 × 15 (P) 30 × 30 (bands 1–5, 7) 60 × 60 (band 6)	15 × 15 (bands 1–3) 30 × 30 (bands 4–9) 90 × 90 (bands 10–14)	20 × 20 (bands 1–3) 10 × 10 (P)
Scene dimensions (km)	185 × 185	185 × 185	183 × 175	60 × 60	60 × 60
Pixels per scene (×10[6])	28	231	231	21	27 (bands 1–3)

* The MSS bands on Landsats 1–3 were numbered 4, 5, 6, and 7 because of a three-band RBV sensor on Landsats 1 and 2.
P, panchromatic mode.

So, here we could just see that this is the LANDSAT this is a some of the summary data of the remote sensing satellites and what is marked here is present is in fact, taken from the (Refer Time: 26:09) exploration that was way back in 2006, so, this gives an idea about what was going on till that time period or what all the satellite data were there.

So, it could see a satellite camera like ASTER which is advanced space borne thermal emission radiation radiometry which operates in the thermal range of the thermal infrared range of the electromagnetic spectrum and you could see the Thematic Mapper which is looking at the multispectral scanner which was working within the wavelength of the spectral bands 4, 5, 6 and 7 the 0.5 to 0.6, 0.6 to 0.7, 0.7 to 0.8, 0.8 to 1.1 in terms of the micrometer.

So, mostly in the visible range as you could see and the Thematic Mapper had bands symbol some of them close to the that of the multispectral scanner, but had the other spectral bands in the longer and the infrared range which was designed to for a better study of the earth materials, where the spectrometry in this infrared range could give much better information as far as the features associated with mineralization are concerned which will be seeing them in a short while.

So, we could see the multispectral scanner in this Instantaneous Field Of View a 79 meter to 79 meter in case of band 1 to 3 and 82 in to 82 into band 4 and here the Thematic Mapper with a ground resolution of 30 meter by 30 meter from the band 1, 5 and 7 and 120 to 120 meters in band 6 and so, this also gives an idea about the amount of data that is generated pixels per scene is 28 into 10 to power 6 means the how many number of such resolution elements could be covered in one scene which would be a certain area that the satellite can recovers and, so, these are essentially visibly you could see that these are the developments of their previous versions.

For example; the Thematic Mapper was a far more useful spectrometer than multispectral scanner similarly the enhanced Thematic Mapper was a better in terms of it is spectral coverage and even the advanced spaceborne thermal emission radiation radiometer was even having much more number of such spectral bands.

So, it essentially means that the as we have discussing about the usefulness of a particular satellite. So, in addition to the ground resolution a satellite also the satellite camera the spectrometer also is it is utility is also judged by the spectral resolution; that means, in what smaller spectral range that the spectrometer is able to process they receive the data and store and process.

So, we will be continuing with these principles and it is utility for mineral exploration.

Thank you.