The Use Of Space Satellite Images in the Exploration for Oil & Gas

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Space Satellite Images have traditionally been widely used in Geology, mainly for various types of Topographic Mapping and for tying together the many types of Geological & Geophysical Data: (eg Well Data, Core Data & Surface Geological observations), or subsurface Geophysical Data: (eg seismic, gravity, magnetic etc).

Recently further applications have been developed for 3D Visualization and for Seismic Survey Planning

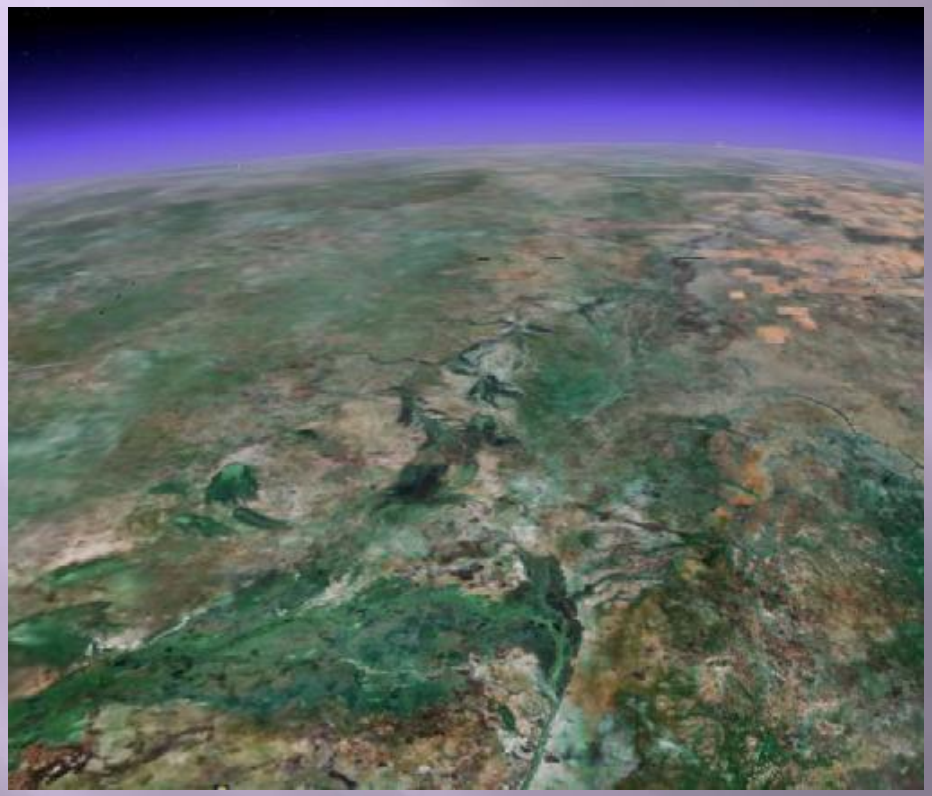
Shift Ilan Lun', China

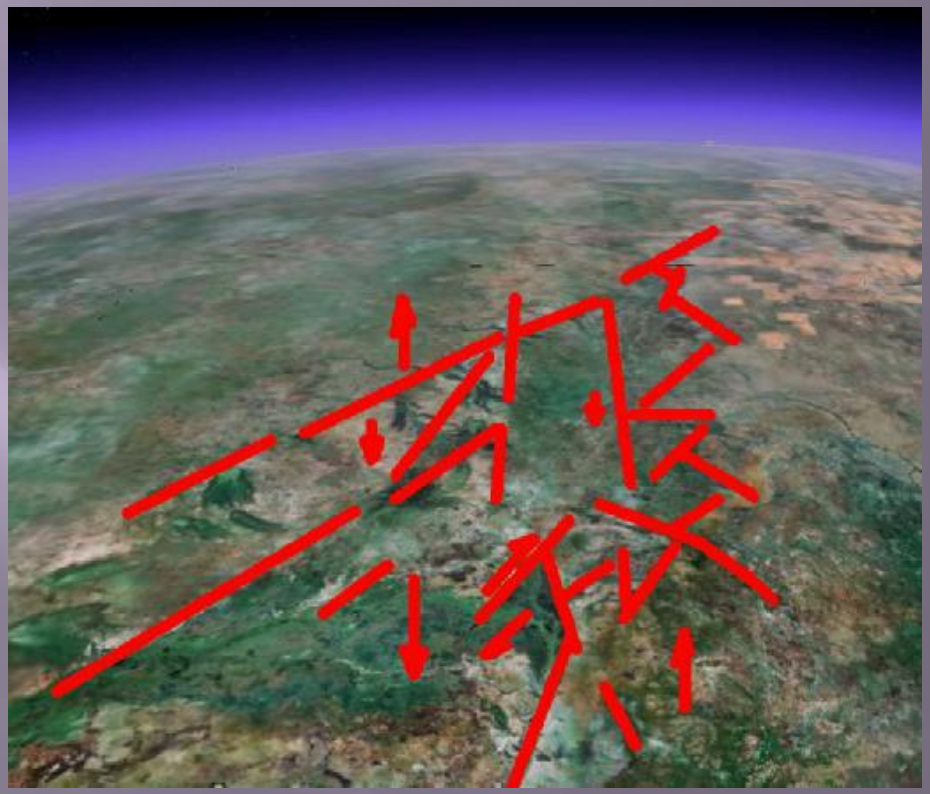
About 50 years ago, Aircraft Images brought a revolution to Geological investigations of the Earth's Surface.

In exposed areas (especially where climates were arid) Aircraft Images allowed the direct examination of lithological and stratigraphic complexes and small-to-medium scale geological structures.

Medium Altitude Aero Image,
the Southern part of Ural Mountain area, Russia.
Folds composed by Limestones (bright strips)
and Aleurolites (dark strips) are clearly seen.

Space Satellite Images provide us with fundamentally new information which cannot be obtained from any other source.

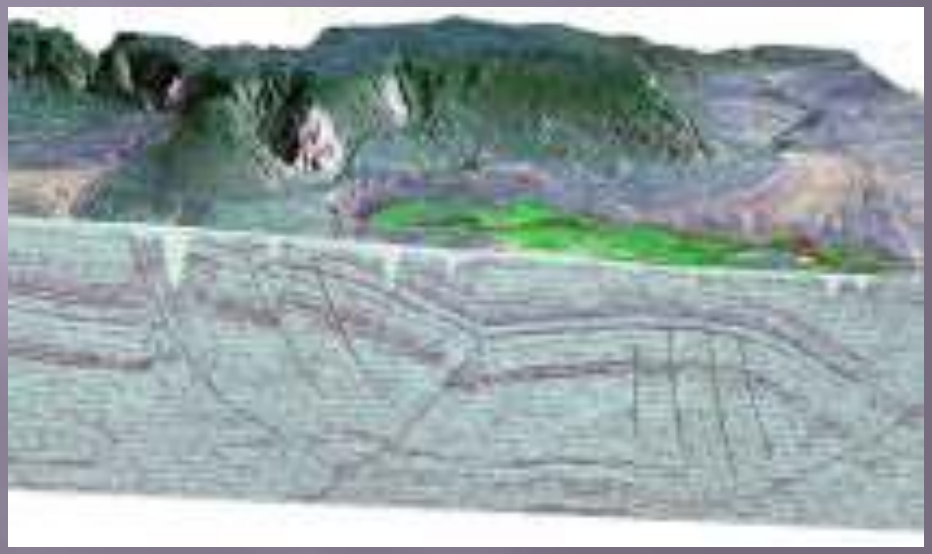




The Faulting of this Graben in Southern Sudan, are clearly seen on the Space Satellite Images, yet these faults are not present on the existing Tectonic Maps of the region.

Traditionally, space images have been used for understanding a landscape and tying existing Topographical, Geological and Geophysical data to the Earth Surface Map.

This does not in itself give any new information about the structure below the surface.



The geological interpretation of space images is based on the correlation of information obtained from space images with other geological & geophysical data.

Such interpretation is based on knowledge of the laws of Hydrocarbon Sourcing, Migration and Entrapment and their detailed relationship with the Geological and Geophysical data available.

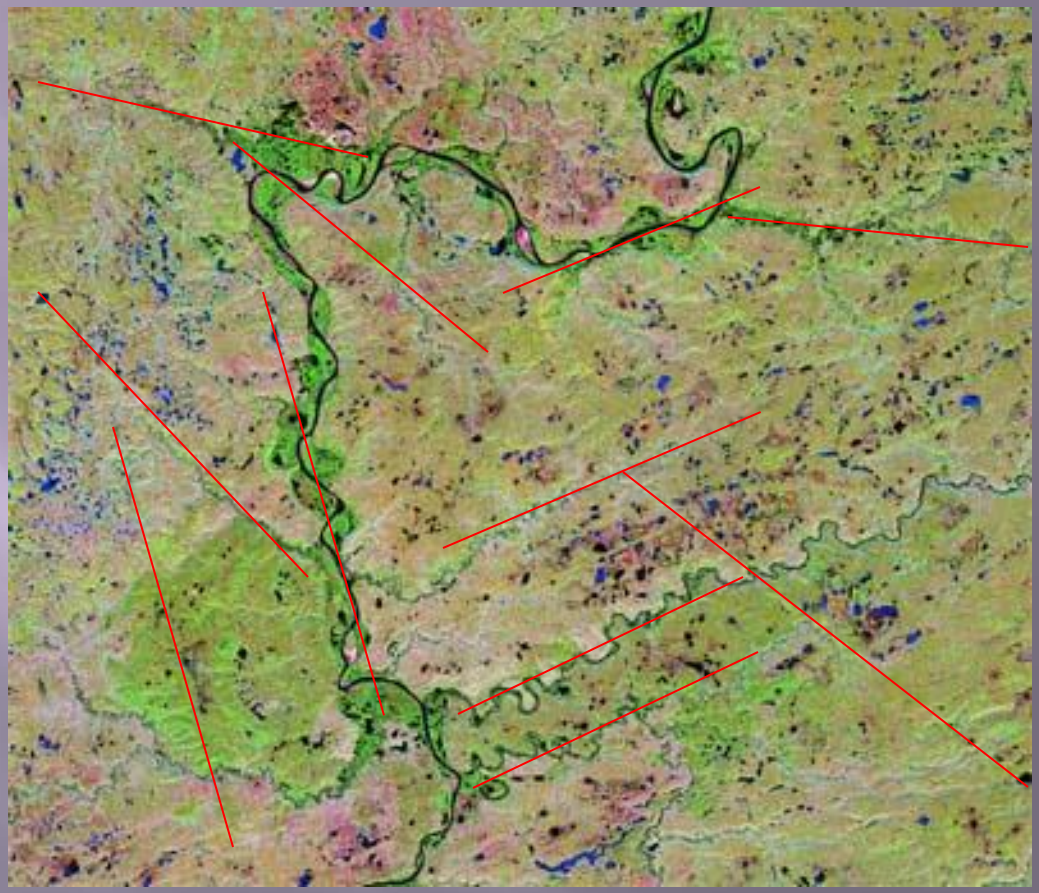
Space images have an advantage - because:

- In general, Geological & Geophysical Data on the Earth's structure is irregular, intermittent and discontinuous.
- A continuous Map or a 3D image may be obtained only as a result of some interpolation. This certainly applies to all 2D Seismic and Drilling Data.
- Aircraft and Satellite data cover territories repeatedly and in their entirety, they give primary information irrespective of what analysts expect. This amount of information is much larger than analysts need or can easily understand.
- With Space Satellite Images we can extrapolate the scarce information. The result is not based on mathematical interpolation, but on the territory's structure seen from the image.
- When Geological and Geophysical data is checked against a Space Satellite Image the information content of both is greatly increased.
- Such images can therefore become the base or "cement" for separate comprehensive studies of an area. This fully enables explorationists to perform combined analysis of all original datasets.

Space Satellite Images can be a useful, and therefore important, tool in the Exploration for Oil & Gas.

Hydrocarbon deposits are generally located deep in the Earth's crust, but they usually express themselves at the surface as anomalies within the landscape.

They may therefore be detected from Space Satellite Images .



Suzunskoe Oil Field,
Western Siberia, Russia.
Using Space Satellite Data,
the fault network was clearly observed,
Using this the Geophysical Data was significantly re-interpreted giving a far better understanding of the Field

If a Prospect or Lead is not seen on the Space Satellite Image, usually structural indications can be observed, such as:-

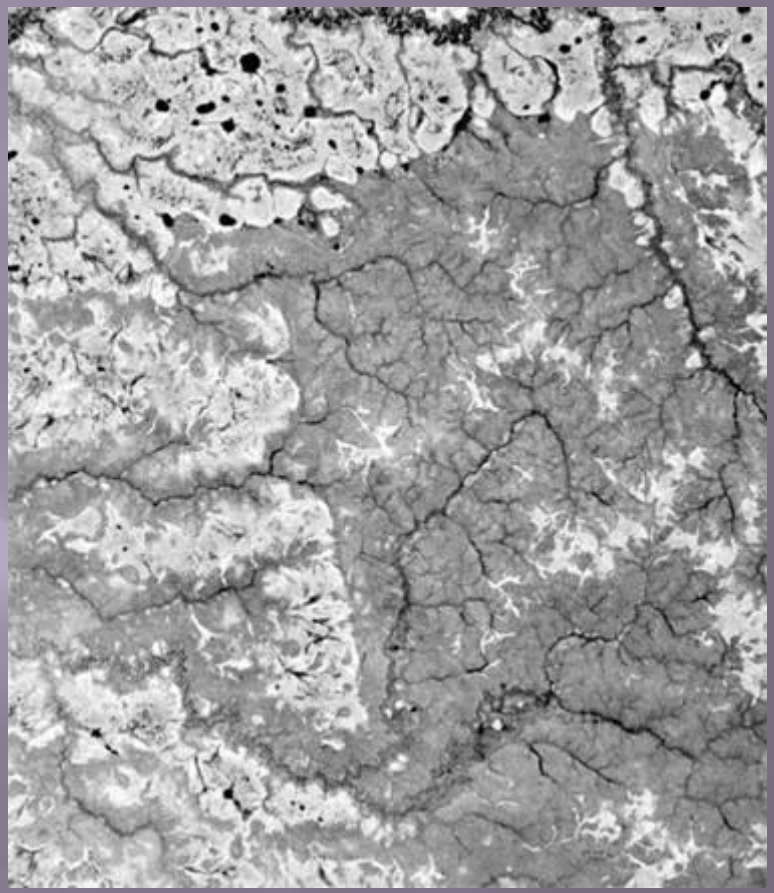
-- locations of faults, or
-- fault blocks which are either upthrown or downthrown

Today there are specialised techniques for the use of Space Satellite Images in subsurface structural analysis.

A set of coincident images at several different resolutions (usually 3), each at many spectral bandwidths, combined with a heirarchal knowledge of tectonic systems are the fundamental ideas behind these techniques.

Yamal peninsula, Northern Russia.
Lineaments cutting the sinking plate, under different resolutions.
The yellow bars show the fragments in the images of larger scale.
Space Satellite Images from: LandSat-7

Landscape details are often indicators of the Deep Structure



Rectangular elements of vegetation. Space image, the river Demyanka, Western Siberia, Russia

Rectangular temporal water river-beds and knee-shaped bends of rivers.
The area of the Sagyz River, Kazakhstan

Landscape components and their combinations allow the detection of the main elements of the structure of the sedimentary cover:

1.) <u>Uplifts</u>,

including local

Anticlinal Structures

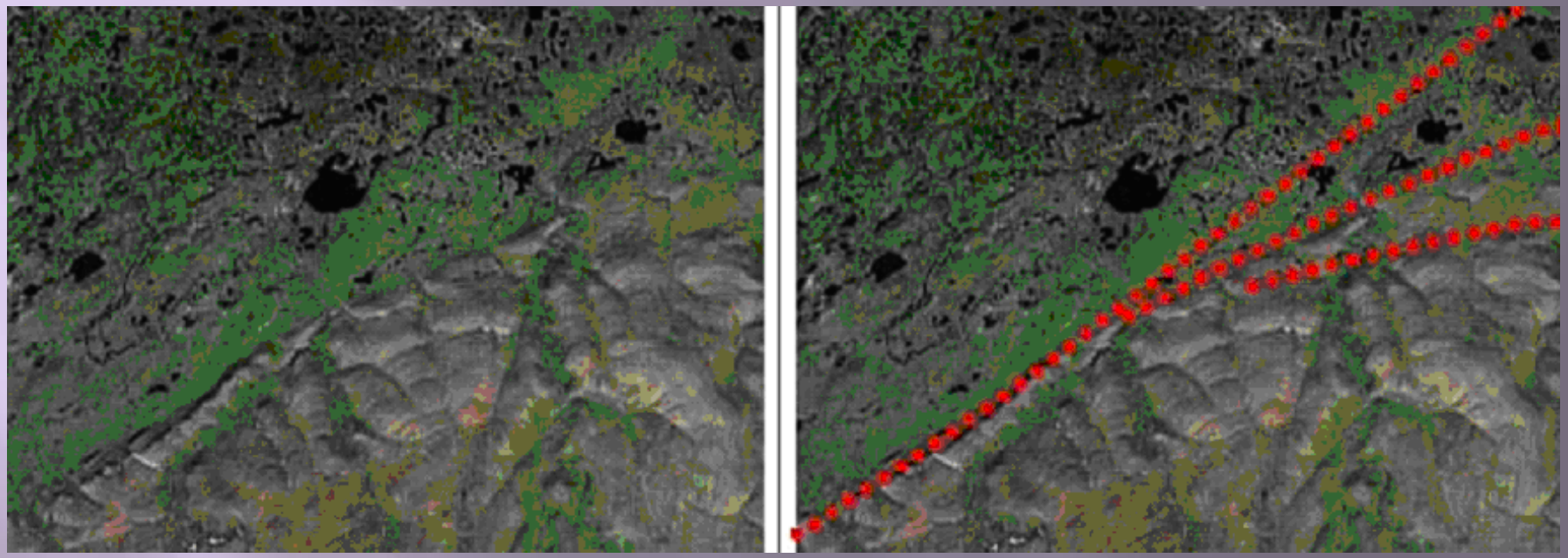
The Ring Structure formed by round arc-shaped river beds is cut by two lineaments in the South.
Southern Sudan, LandSat-7, panchromatic image.

2.) Downfolds

The Southern part of the Preduralsky Downfold is shown between The Ural Folded System and the East-European Plate. In the SW part of the image the northern fragment of the Prikaspiysky Basin is seen.

This image covers part of the Russia-Kazahstan Border

3.) Structural Steps



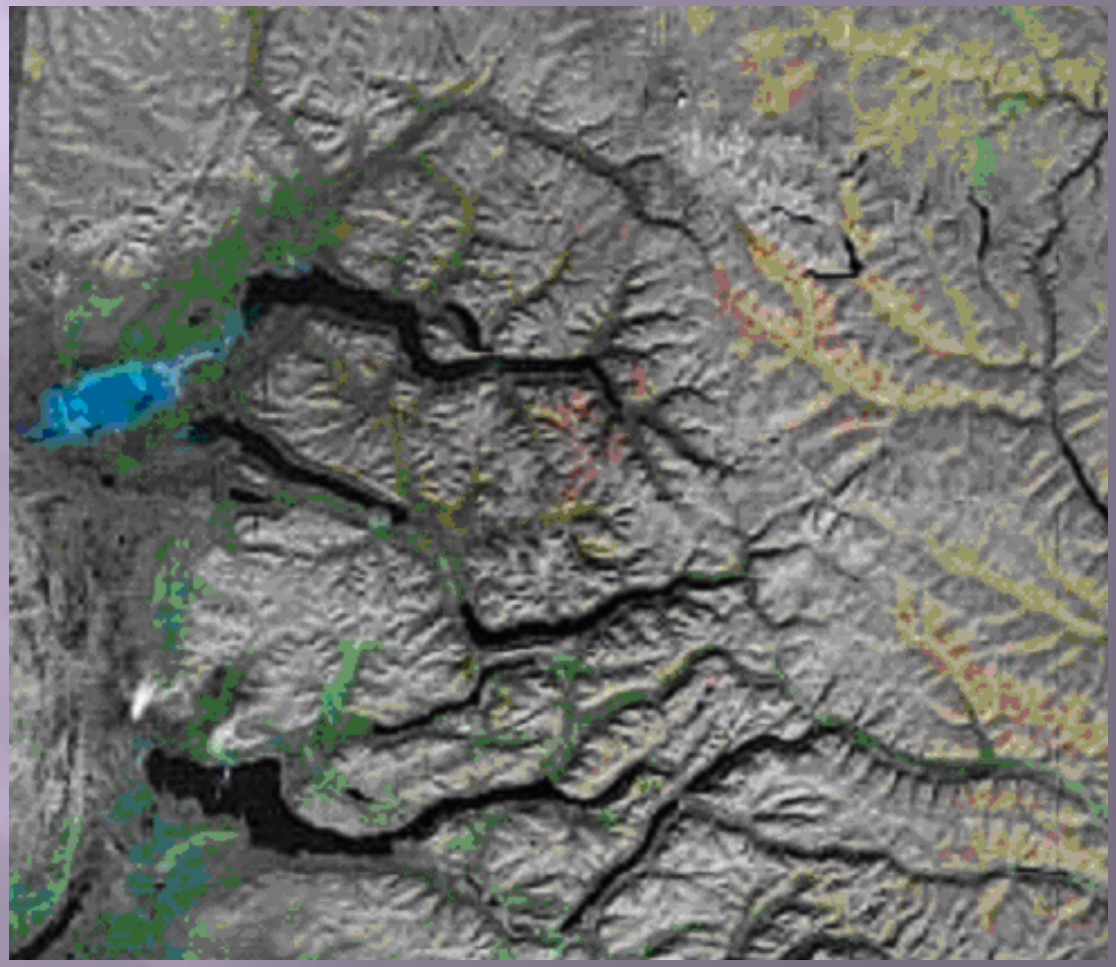
The Rectilinear Boundary between mountain and low-lying relief areas which reflects the “Structural Step”.

This Image shows The Boundary of Plato Poutorana and The North-Siberian Plain, Russia.

4.) Disjunctive Elements and Faults …

Southern Sudan, an Aerial Image.
(tilted to about 45 degrees from vertical.)

These “Disjunctive Elements and Faults” sometimes form a regular network which then clearly illustrate the local geodynamic situation.



Plato Putorana, Siberia, Russia

Ring Structures:

These are often accompanied by Radial Lineaments. Such Lineaments are, in turn, often indicators of anticlines, or geochemical & thermal anomalies connected with Oil & Gas reserves.

Muglad Basin, Southern Sudan.

Anticlinal Folds:

These are usually clearly observable at the surface. They can be identified by systems of Ravines, Rivers and Waterways. The latest tectonic uplifts are the best background for detecting them. Even human industrial activity leaves them generally clearly detectable.

A Ring Structure above the Boukharskoye Oilfield, in the European part of Russia.

The structure size is around 4 km.

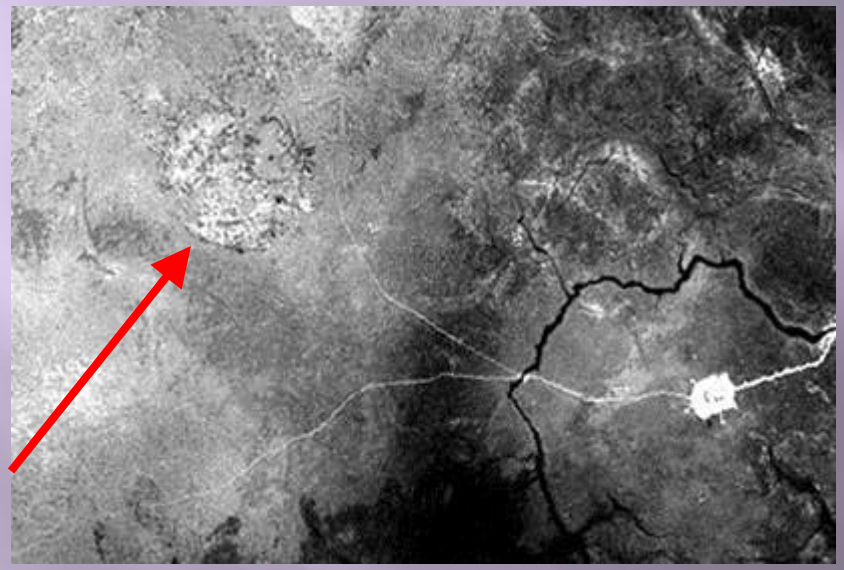
Aerovisual Observations

are the best way to confirm that the information taken from the Space Satellite Images is reasonable, and representative of the Subsurface Geology.

Human contamination in the form of crop boundaries, crop-burning boundaries, plantations, roads, canals, railways, pipelines, power-lines, fences, etc can (once observed) be manually edited from the computer-based correlations and lineaments derived from the Space Satellite Images.

Such Aerovisual Observations are especially important wherever Space Satellite Image interpretation has not been previously done.

This is because structures not related to geology may be mistaken as having a geological cause.



Left:- Man-caused "Ring Structure" shown by the red arrow.
Right:- Tammor Oilfield and the associated "Ring Structure" The well Tammor-1 with access road is also clearly visible (green arrow). Location:- Southern Sudan

Typically lineaments seen on Space Images are compared with the results of Oil & Gas Exploration from Geophysics and Geochemistry (Thermal Fields, Chemical Composition Anomalies etc.)

Structural Map based on Geophysical and Drilling Data.
Depth Contours to the Top Trias Surface are shown (in km).
Main Faults (solid line),
Lineaments revealed by Satellite Images (dotted line),
Photo Anomalies (hatch areas).
Location:- Bousachi Peninsula, Kazakhstan.

In the previous work in Sudan, the CST team used an improved technique derived from a standard mandatory procedure in Russian Oil & Gas prospecting which demands the presence of Space Satellite Images.

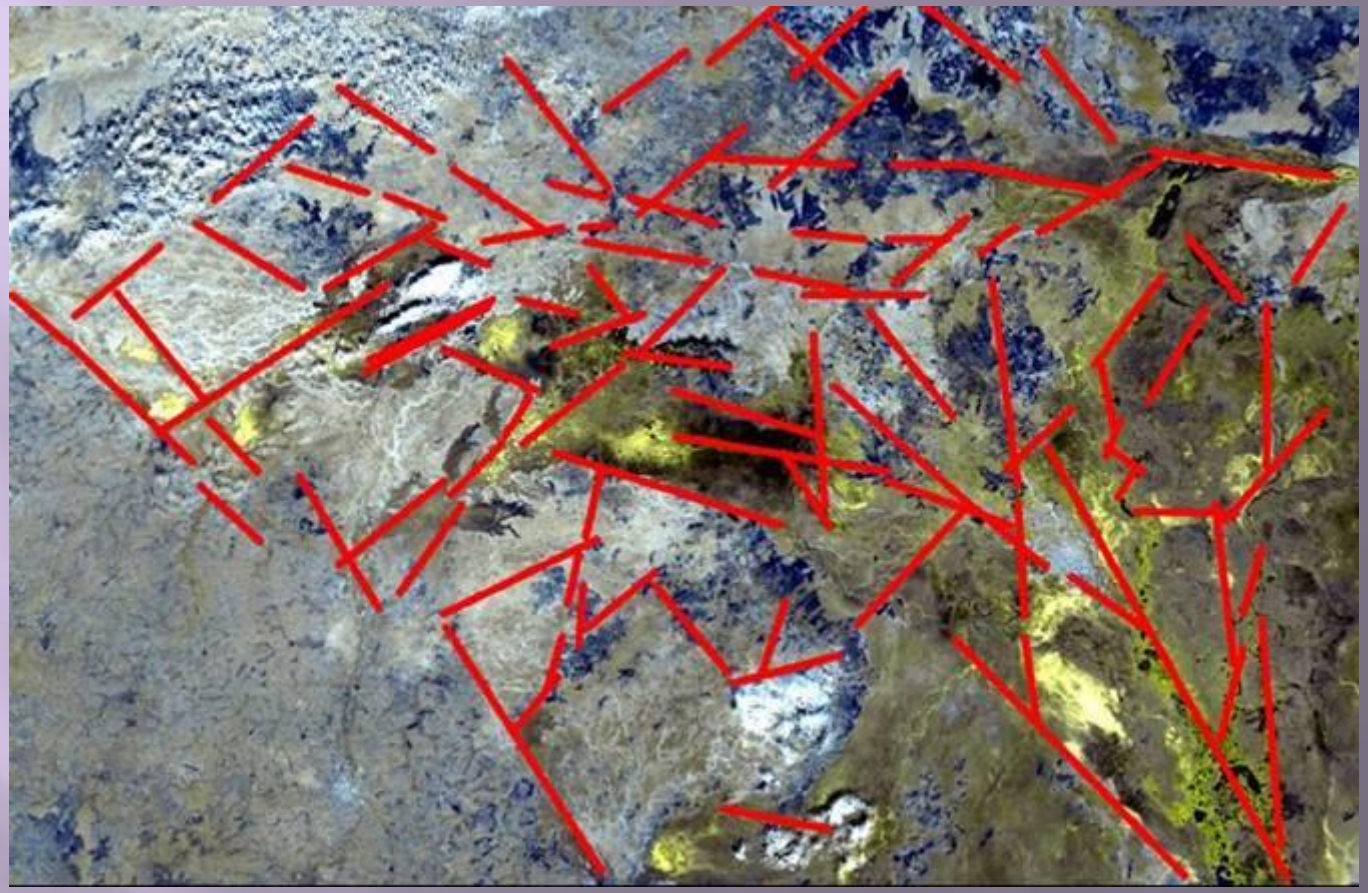
The key expertise needed is experience in knowing how to use images of different resolutions, and covering areas of different sizes, to reveal particular geological structures.

Combined with other conventional Exploration Data it makes the prospecting for Hydrocarbons much more reliable and as a consequence much more **Economical** !!

Example – Southern Sudan

The assessment of a region using a Satellite Image at the "Regional Scale"

Example – Southern Sudan



Main structural features after the studying the Mid-Range Resolution Image (Nominally 100 m resolution).

Example – Southern Sudan

The detailed map (Main Structural Elements) is not shown due to client confidentiality. (GNPOC property)

Space Satellite Images of certain types (eg: Infra-Red, Ultra-Violet, or Radar) clearly reveal Geological Objects that might otherwise be disguised.

For instance, those covered by a thick sand layer like in Northern Sudan, or Southern Egypt.

Radar Image of the middle course of The Nile, Egypt.
The bed rocks normally covered by sand are clearly seen.

This technique can be applied:

1). At the stage of Hydrocarbon content forecasting (scale 1:1,000,000 – 1:500,000) for detecting the main anomalies in Faulting & Block Structures in the area.

2). Choosing the main Fault directions and top-priority Geological Objects for further exploration: including the location of seismic profiles. Such studies can be carried out with very limited Geological or Geophysical data, even in their total absence.

3). For the determination of sub-regional and zonal structural relationships between various morphology patterns.

4). As a result, the most promising trap areas can be located, and the areas for detailed seismic surveys, and possible geochemical sampling can be chosen.

The method may be applied :

1). At the stage of identifying Geological Objects for detailed Seismic (or other) Surveys.

2). For the preparation of such Geological Objects for exploration drilling: should such surveys confirm their prospectivity.
(Recommended Mapping Scale 1:200,000 or larger).

3). To identify bedding conditions at the proposed Hydrocarbon-bearing locations; and therefore possible drilling hazards.

4). For mapping of all the possible hydrocarbon traps and identifying the main features of their structure. If only 2D seismic is available, maps derived using Space Satellite Data in addition will be a significant improvement. (EG. Fault alignments between seismic lines will be much less ambiguous).

For optimum results:

- At least some seismic data, well data and possibly other geological and geophysical data are needed. The final "Holistic" interpretation is generally most accurate the more separate, high quality datasets are available to be fully linked using the Space Satellite Images as the "glue".

- At this stage of "Prospect Mapping" a mapping scale of 1:100,000 or larger is recommended: for Prospect delineation and to assist in detailed Fault mapping. Faulting of course being important for both Prospect Structuration, and Hydrocarbon Migration.(e.g. Fissure Zones).

Exploration for Oil & Gas is not the only Geological use of Space Satellite Images. Other Geological uses include:

- For Minerals & Metal Ore deposits. The geological relationship between most ore deposits and magma and volcanic massifs, with secondarily changed rocks, are well known. Thus, at the Earth's present-day surface (or close to it) the mineralization zones usually form specific macro and micro relief, which is seen in Space Satellite Images.

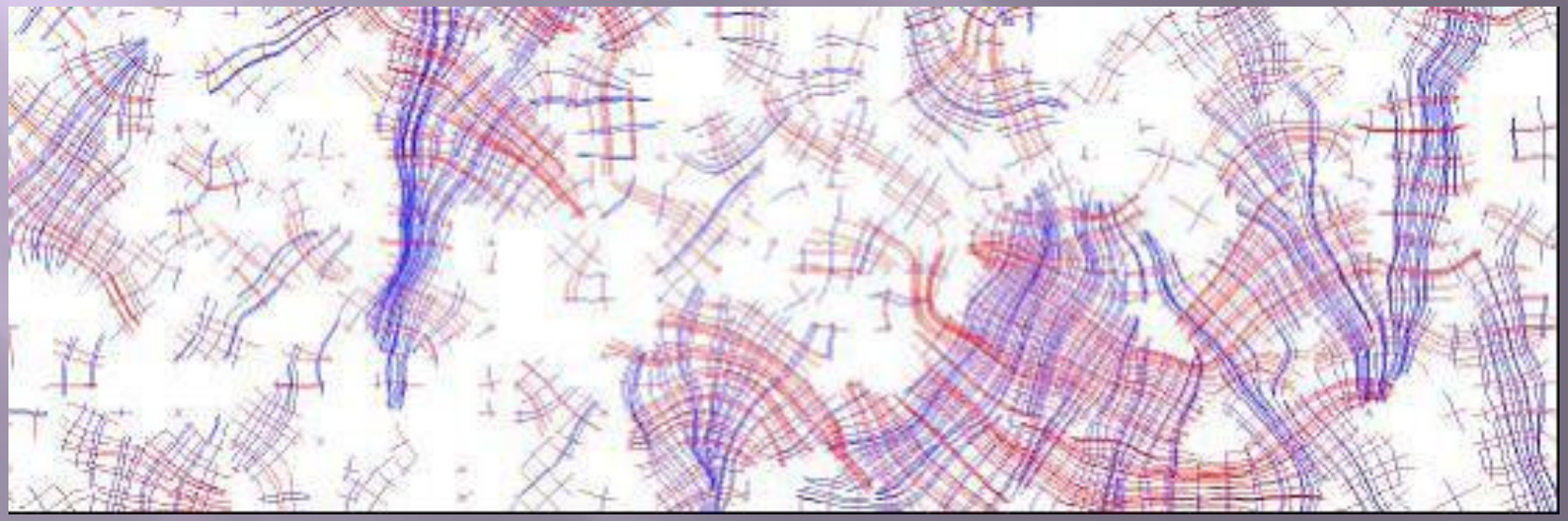
- Groundwater Exploration. Artesian basins usually also correlate with tectonic structures which may be detected from space.

- Real-estate Evaluation. Based on space images, rapid evaluation of plots before purchase is possible.

People Matter !!

Despite the fact that the interpretation of Space Satellite Images is always done with the help of the latest advances in science and computing, the key factor, as in most Professional interpretations - be they: Legal, Medical or Geological, is the experience and qualification of the professionals.

C.S.T. uses World-Class specialists in Space Satellite Image interpretation for geological and geomorphologic applications.



Typical results of the interpretation of space images integrated with already existing geological and geophysical data are as follows:

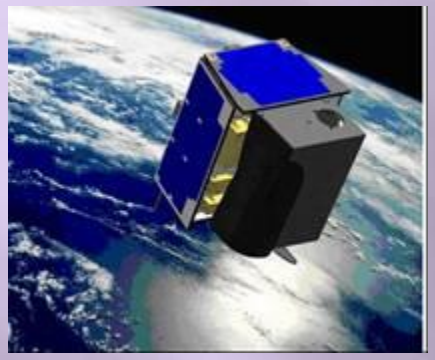
- The map of main faults/lineaments with classification of faults by size and possibly kinematics;
- The location of ring structures and modern rises;
- The scheme of sedimentary cover base created by complex interpretation of space and surface data;
- The structural scheme of the target reservoir surface created by complex interpretation of space and surface data

Usually the work on oil & gas prospecting with the help of space imagery has the following stages:

1. Agreeing main goals of the work in collaboration with a customer.
2. Preparing the initial data set (topographic, geological, geophysical data).
3. Preliminary interpretation of “Overview Scale” space images.
4. Preliminary complex interpretation of space images and geological and geophysical data.
5. Choice of scales and interpretation methods for the “Detailed Scale” space images.
6. Interpretation of the “Working Scale” images; creation of preliminary model of the territory.
7. If needed – field aero visual surveys.
8. Re-interpretation of all the collected data.
9. Creating final maps and preparing recommendations for further detailed surface works and drilling.

The success of a prospecting project based on space imagery is often connected with the tectonic and landscape features of the area under a study. But in general, it is possible to adjust the technique by choosing scales, final maps needed, etc. Also, the stages of work can be optimised.

Capabilities of VNIIEM :– the leading organisation in Russia in charge of remote sensing of the Earth



The Russian Federal State Enterprise "VNIIEM" is a pioneer in development and production of space vehicles for remote sensing. It created the first "Sputnik"& many Surveillance Satellites up to the recent:- "Meteor" (a Meteorological Satellite), "Meteor-Priroda" & "Resurs-O" (Natural Resource Satellites).

At present "VNIIEM" develops the space vehicles for the Russian Federal Space Programme (until 2015), for Hydro-Meteorological monitoring "Meteor-3M" and for Space Remote Sensing "Kanopus-V". It also does research into creating new devices and methods for remote sensing.

In studies done in USSR for the "Interkosmos Programme", (as reported at the International Geological Congress, Moscow, 1984), a world-first for Space Images was obtained: an Oil Discovery in the Bousachi Peninsula was proposed, drilled & confirmed from interpretation of Space Images alone! The scientific head of that study was Prof. P. Florensky who had previously shown in 1972 that Oil-bearing structures not even seen in Aero Images can be observed on Space Images.

Today, the interpretation of Space Images for Oil & Gas Exploration is carried out in VNIIEM by leading Russian specialists who have extensive experience of different Geological and Topographic conditions. This experience has been gained in Russia (plus former USSR) and abroad (eg:- Algeria, Mauritania, Mali, Sudan, etc.).

Conclusions

(1) We are surveying by a fundamentally new Space Satellite Interpretation Method.

(2) We have recently proven results, building on years of successful Exploration Results of experienced personnel using each constituent part of the Method.

(3) Most – if not all – the Space Satellite Data you will need is on the shelf - now.

(4) Extending the Geological Knowledge learnt from all your Wells, Seismic and other sources, by fully integrating it with the Space Data is the most cost-effective way to extend that knowledge and Exploration Success.

(5) CST, VNIIEM, and experienced associates are currently available, for a limited time, to work on additional projects. Costs are in the range of 20,000 – 800,000 Euro.