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Proficiency and Protocols of Geomatics in Ground water Exploration

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Abstract: *The water resources management has ever remained an issue of major challenge due to the exponential population explosion and the inadequacy of the available surface water resources to cope up to the Man's growing demands. These triggered manifold explorations to hunt for more water resources, especially the ground water reservoirs and develop plans for managing them. Though many tools and techniques have all along been used, it is only the Geomatics technology, comprising dominantly the Remote Sensing and GIS, has proved its advanced proficiencies in providing newer insights into the issues of water resources. But still there is hierarchy of issues in water resources and we will have to go a long way in capitalising the virtues of Geomatics technology. The paper deals with some of the advanced proficiencies of Geomatics technology and how precisely it can provide solutions in ground water related issues when this technology is used appropriately following the fool proof protocols.*

Key words: *Geomatics, rock type mapping, tectonic and geomorphic analysis, ground water mapping*

1. Introduction

The water continues to remain a scarce commodity since several decades and it is attributed to the disproportionate population growth and the resultant inadequacy of the existing surface water resources to cope up with Man's demands. Hence the Geoscientists and the technocrats from all over the world have started exploring the ground water resources using various techniques like field based hydro geological mapping [1-8], geophysical explorations [9-11], Geomatics or Remote sensing and GIS based investigations[12-18] . But despite all these multivariate tools and techniques, the ground water targeting remains enigmatic, especially in hard rock systems owing to their inherent heterogeneity of the aquifer systems. On the other hand, the flood water harvesting too , both by storing at the surface and by recharging it into the deeper parts of the aquifer systems are yet to see the light of the day , as we don't have concrete plans or models to accomplish it.

Under this scenario, though the Geomatics technology has been widely used for the past 4-5 decades and packages of newer information were brought out on ground water, still there is bee-line of issues to be solved, especially in targeting the potential ground water locales. The present paper deals with some of the unexplored virtues vested with Geomatics technology, which can give precise models and solutions on the various issues confronting the ground water systems.

2. Proficiency and Protocols of Geomatics in ground water prospecting

2.1. Mapping rock types for ground water

The primary porosity of the sedimentary rocks in the form of grain size and the secondary porosity in the form of fractures and faults in the rocks are the proven loci for ground water. While the raw satellite multi-spectral data possess the credentials of discriminating the sedimentary and hard crystalline rocks ,these data under various digitally processed modes have advanced credentials in the discrimination of rock types of all parentages and from it, precision can be achieved in ground water targeting and management. The grain size while form the major determinant of the primary porosity of the sedimentary rocks, the folds, fractures/ faults provide secondary porosity to the hard crystalline rocks, and these in turn assign overall texture to the rocks. So, if suitable digital image processing of any satellite multi-spectral data is done, which can enhance the textures of the rock types, it can lead to precise discrimination and mapping of rock types.

For example , digital image processing of LANDSAT TM data carried out for Ariyalur area, Tamil Nadu, India, using the normalized rationing techniques with bands 1+5/1-5, and further filtering using Sobel 7 filter show distinctly three rock types of contrasting textures (Fig.1). The impervious clays (1) and the pervious sandstones (2) of Ariyalur Group of the Cretaceous period, respectively show ultra-

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smooth and coarser textures. Similarly, the Precambrian gneisses (3) also display coarser texture due to fracturing, differential weathering and sedimentation (Fig.1). However, there appear to be a difference in the coarseness with little more coarseness in sandstones and less in the gneisses which indicates that sandstones are more porous than the gneisses. Thus the rocks of different porosities and permeabilities can be mapped precisely and the porous ones can be used for ground water targeting and recharge and the impervious rocky provinces for surface water storage reservoirs.

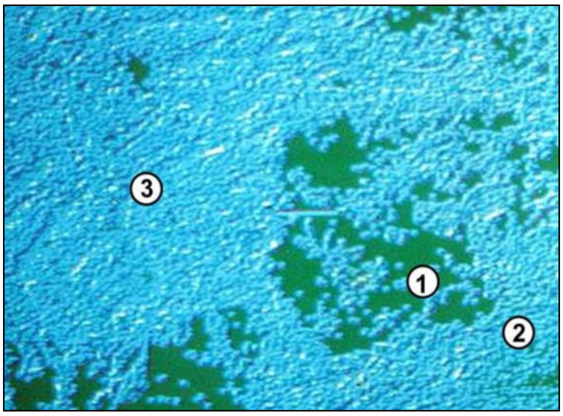

Fig.1: *Digitally Processed LANDSAT TM data of Ariyalur area ,Tamil Nadu showing impervious Cretaceous clay with ultra smooth texture (1),highly pervious Tertiary sandstone(2) with more coarse texture and moderately pervious Precambrian gneisses (3) showing moderately coarse texture*

While the simple normalized rationing and filtering techniques could provide such vital information on porous and impervious rocks , the advanced statistics driven digital image processing of satellite multi spectral data can provide much more information on the rock types , their inherent primary porosity ; the degree of deformation , weathering and the resultant secondary porosity, which all have direct bearing over the ground water systems. The studies carried out in Ariyalur area, Tamil Nadu, India which exposes the Pre Cambrian hard gneissic rocks in the west and the sedimentary rocks belonging to Cretaceous and Tertiary periods in the east show the proficiency of the statistically processed satellite data (Fig.2). The said study was carried out by (i) taking a test window of 300 pixels and 300 scan lines (90,000 pixels) from the six spectral bands (except thermal band) of LANDSAT TM data (ii) keeping the 90,000 reflectance data as the samples and the six spectral bands as six variables (iii) carrying out multiple regression analysis following the model of Davis [19] (iv) estimating the constant and the regression coefficients 'B' of all the six bands and (v) spectrally merging all the six bands using the regression equation and generating a single band of TM data and (vi) finally executing the supervised classification of such single merged band. Such supervised classified image show that the Precambrian rocks like charnockite (1), gneissic rock cut pediments (2) and highly weathered Gneisses(3) are precisely discernible(Fig.2).Similarly, while the ratioing and the filtering show only the clayey and non clayey formations in the sedimentary rocks , the present technique show clear variations within the sandstones Viz; arenaceous (4) and the clayey sandstones(5) in the younger Cretaceous rocks (Fig.2). So, these types of advanced techniques can be used for detailed ground water explorations from the lithological points of view.

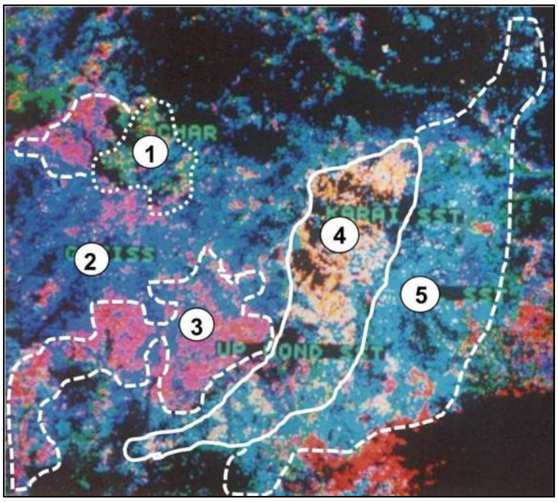

Fig.2: *LANDSAT TM classified data, Ariyalur area, TN, India showing Massive charnockite (1),Gneisssic pediments (2), highly weathered gneisses (3), of the Precambrians; Arenaceous (4), and clayey sandstones(5) of Cretaceous formations*

2.2. Mapping of folded structures for ground water

The structural deformations in the form of folds and faults and the resultant architecture of the rocks have greater control over the ground water systems, thus demand deeper attention. The satellite based Remote sensing has advanced proficiencies in exhibiting the deformational pattern, due to their synoptic view provided by these data sets, in contrast to the field where these can be perceived only within the visibility range of the human eyes. Though a lot of studies have been carried out on the lineaments and fractures for ground water assessment [20-25], not much of attention was given to the folded structures, despite the exhaustive vistas available with geomantics. For example, the unfractured basins and doubly plunging synclinal structures, whether exposed at the surface or occurring under near surface conditions, form avenues for pseudo perched water table conditions. The satellite data in its raw and digitally enhanced modes can explicitly display such structures when are exposed at the earth surface, whereas when these occur at shallow depths or deeper, will show ring or elliptical structural trends similar to cut onions in satellite data and aerial photographs. Similarly the domal and doubly plunging anti formal structures can also be precisely mapped from satellite data which are unfavorable zones for ground water as well as for artificial recharge.

The doubly plunging synformal structure of Andipatti area, Tamil Nadu, India, (Fig.3) is a good example for demonstrating the control of the folded structures over ground water. While the individual layers of the rocks display the structures clearly with the curvilinear and curved structural trends (1), the cultivation seen with red tone in FCC satellite imagery and dark grey tone in black & white imagery (2) within the synformal structure shows that it acts as favourable zone for pseudo perched water table (Fig.3). Such types of signatures revealed by the satellite images need to be studied for optimally utilizing them for ground water management.

At the same time, mapping of such folded structures acting as favorable loci for perched water table conditions are not easy, because of the fractures and faults available, if any, would make such structures leaky ones, thus making them unsuitable for groundwater accumulation and storage. Hence the fractures and their dynamics should also be studied while evaluating these folds for groundwater. The aerial and satellite-borne Remote sensing data provide adequate avenues for it. The kadavur basinal structure located south of Cauvery river near Tiruchirappalli, Tamil Nadu, stands as a testimony for the same (Fig. 4& 5).

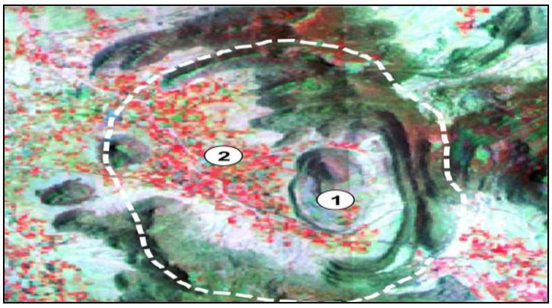

Fig.3: *IRS 1A FCC of Andipatti area, Tamilnadu showing doubly plunging syncline (1) in gneissic Pre Cambrian rocks causing pseudo-perched water table (2) Conditions*

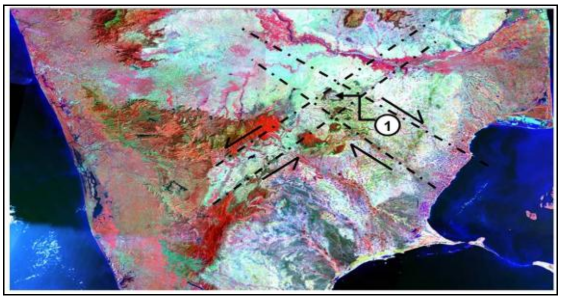

Fig.4: *IRS 1A FCC of parts of South India showing faults Bounded and faulted Kadavur ring structure in Pre Cambrian Quartzites*

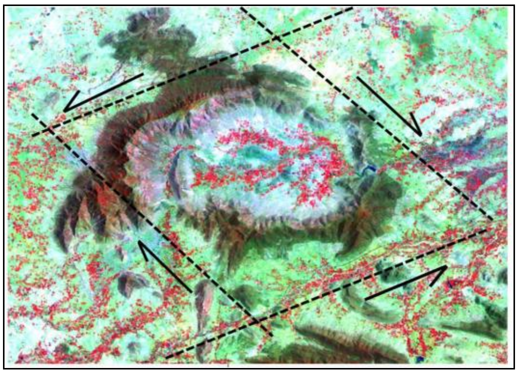

Fig.5: *IRS 1A FCC showing Kadavur Ring structure, in Pre Cambrian Quartzites, Tamilnadu, bounded by NE-SW sinistral and NW-SE dextral strike-slip faults*

The Kadavur ring like Precambrian quartzitic hillock forms an overall basinal structure. If it is simply mapped as a basinal structure, then it appears to have better prospects for ground water. But, if the associated fractures and faults are mapped, it is confined within two NE-SW sub-parallel sinistral faults and NW-SE oriented sub-parallel dextral faults (Fig.4&5). These were explained to be active faults related to the post collision tectonics of the Indian plate due to which, the basinal structure is under the grip of sinistral and dextral couples [26].These sinistral and dextral couples have caused warps, folds and number of minor faults within the structure due to the N-S greatest principal stress which has drifted the Indian plate towards northerly [26]. Under this stress regime, the Kadavur Precambrian basinal structure must be currently undergoing wrench fault tectonics (Fig.5) and because of such wrench fault tectonics, the above warps and faults are preferable to 1st and 2nd order warping and faulting [27,28]. Hence, the ground water holding capacity within the Kadavur structure should be poor. It follows from it that all the basinal and doubly plunging synformal structures may not be favorable zones for ground water accumulation and it depends on the fracture/fault systems and related geodynamics. The satellite borne remotely sensed data provides potential baseline information in studying such folded structures in detail for ground water prospecting as demonstrated by the Kadvur basinal structure.

2.3 Mapping fractures for ground water

2.3.1 Fracture revealed by satellite data

The occurrence of ground water along the lineaments/ fractures in hard rock's is the proven fact and lots of studies have been carried out on these since several decades. However in the recent decades, studies have been initiated and going on in multiple directions using the technologies like Remote Sensing, GIS, geophysics etc. But, the precise ground water targeting still remains a matter of enigma. This may be partly due to the inherent heterogeneity of the fracture systems, especially in hard rock terrains, or due to the lack of deserving importance given to the dynamics of the fracture systems while studying them. But, there remains hierarchy of vistas with satellite borne multispectral data and the GIS based geospatial and geo statistical analysis.

For example, the water bearing and water barren lineaments have contrasting tonal expressions in the raw and digitally processed satellite data. In general, the water bearing lineaments will show alignment of vegetation along them, which in turn will exhibit deep red tone in False Color Composites and dark grey tone in black white satellite imagery. Again the thermal bands of the satellite data will exhibit darker tone along water bearing lineaments because the cooler signatures due to the water content along them [29]. One such IRS 1-A FCC data of Tiruchirappalli region, Tamil Nadu, India, is shown in Fig.6. It shows spectrum of North- South Lineaments (Fig. 6) with vegetation alignment along them. Amongst these, the N-S lineament (1, Fig.6) seen in the west shows only spectacular vegetation alignment along it .Similarly, the lineament 2 (Fig.6) which cuts across Cauvery, extends in the north and forms a well-defined fault line escarpment along the eastern boundary of the Kolli hills also shows vegetation alignment. But in both cases, no perceptible drainages are seen. This shows that only because of the ground water flow along them, these host vegetations along them. Whereas the other N-S, NNW-SSE and NNE-SSW lineaments 3, 4 and 5(Fig.6) do show similar vegetation alignments along them, but along with drainages. So these lineaments are also ground water bearing ones and in addition these have recharge possibilities also from the drainages .So, from such tonal contrasts such ground water bearing and also the lineaments witnessing natural recharge can be mapped.

2.3.2 Morpho dynamics of fractures and ground water

Further these north- south lineaments of Tamil Nadu have been documented to be the post collision extension faults with wide open morphology due to the still active northerly directed compressive force, which only originally drifted the Indian plate towards northerly [26]. These set of lineaments exhibit varied manifestations in parts of Tamil Nadu viz; frequent seismic tremors, landslides and palaeoscars, mud eruption, drainage reversals and drainage deflections, fault valley, deformation of coastal sediments etc in the central parts of Tamil Nadu [30]; and active block faults with uplifts of Mio-Pliocene sandstones along the coast in Vedaranniyam region [31], all indicating better ground water prospects along the N-S faults/lineaments. So, such N-S active faults are genetically water bearing owing to their wide open morphology, which is also well manifested in the tonal contrasts as discussed above.

The satellite images in black and white modes are also capable of showing fractures and faults of different morphologies and dynamics as shown by the ERTS imagery of parts of Appalachean Mountains (Fig.7). The same shows fracture systems of three contrasting morphologies with North-South wide open (1), East-West marginally open (2) and the Northeast-Southwest tight (3) fractures (Fig.7). So obviously, fracture group-1 will have high ground water prospects, followed by 2 and the fracture system 3 would have least prospects. Similar observations have been made in parts of Tamil Nadu also [14] that the fractures/faults orthogonal to the fold axes are wide open and have better ground water prospects due to their extensional origin, followed by the fractures parallel to the fold axes, as these are release fractures and the fractures that are conjugate to the fold axes have least prospects because of their transverse movements.

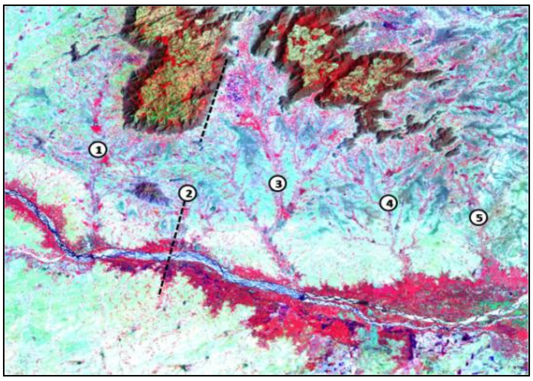

Fig.6: *IRS 1A FCC data of Tiruchirappalli region, Tamilnadu showing N-S water bearing lineaments /faults with distinct darker/red tone*

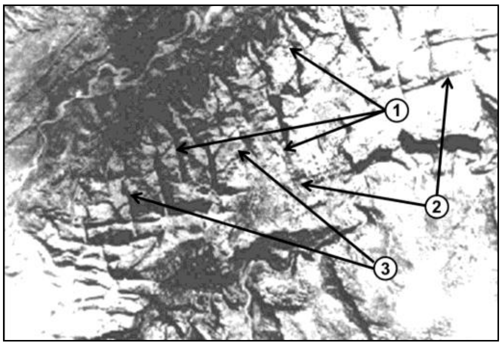

Fig.7: *LANDSAT data of part of Appalachean Mountains showing wide open N-S(1), marginally open E-W(2) and tight NE-SW (3) fractures of different ground water conditions*

The remote sensing technology also possesses proficiency in mapping the lineaments and faults of repetitive tectonism over the geological periods and such time transgressive faults, if mapped precisely, can provide advanced information in ground water prospecting. One such a study carried out by the senior author [32] shows that as far as the Precambrian tectonics is concerned NE-SW faults are dextral and NW-SE faults are sinistral related to the near E-W compressive force; whereas the NE-SW and NW-SE faults are respectively sinistral and dextral in morphology due to post collision tectonics of the Indian plate, which indicates that these two Precambrian faults have moved in opposite directions during Post collision tectonics event. The study[32] further inferred that whether the dextral faults have moved sinistrally or the sinistral faults have moved dextrally, these transverse movements would normally tighten the fractures and thus it should be ground water barren; but in the case of Tamilnadu, these NE-SW and NW-SE faults act as good ground water prospects in several places; from these it was surmised by the study [32] that during the post collision tectonics, the Precambrian faults might have been closed in some segments and in some sectors it would have been opened. Thus this study [32] suggested that the fractures and faults need to be studied critically, for which the geomatics technology have extensive scope.

2.3.3 Spatio- linear modeling of fracture systems

In addition to discriminating the water bearing and water barren lineaments directly from the tonal contrasts in black and white satellite VNIR data, mapping the morphology and dynamics of the fractures/faults and assessing the time transgressive tectonics, the Geomatics has credentials in discriminating the fractures of high transmissivity, storage coefficient, permeability and other various aquifer parameters using spatio-linear modeling techniques. In this, (i)the fractures mapped from remote sensing can be classified into 36 azimuthal classes of 10 degrees each (N00^0-10^{0}E, N10^0-20^{0}E, N20^0-30^{0}E etc), followed by (ii) the generation of 36 individual GIS layers on these fracture systems (iii) generation of numerical data bases for 500 grids of 10 sqkm each for each of the 36 azimuthal frequency of fractures by measuring the total length of fractures per unit grids by the superposing the grid map over the 36 GIS layers of various azimuthally frequency of fractures (iv) generation of similar 500 numerical data for the same 500 grids on transmissity, permeability, storage coefficient and other aquifer parameters data from the adequate number of pump tests data (v) and then carry out multiple-regression analysis [33] by keeping the 500 numerical values of the transmissivity as dependent variable and the corresponding 500 numerical values of 36 azimuthally classes of fractures as 36 independent variables. Then from 36 regression coefficents accrued so, the azimuthally classes of fractures that show maximum correlation coefficients with the transmissivity can be identified and mapped as fractures of high transmissivity. Similarly, the maps on the fractures of high storage coefficients, high permeability and shallow ground water conditions can also be brought out. The study carried out in parts of Central Tamilnadu which showed that the fractures falling in N20°-10° W & N60°-80°E directions are of high transmissivity in nature (Fig.8).

So, the simple lineament or fracture pattern mapping and marking their density maximas as potential zones for ground water, as is being generally done may not be sufficient and their detailed morphology, dynamics and methods like strong GIS based statistical modeling using the proficiency of geomatics technology are essential for proper ground water development and management.

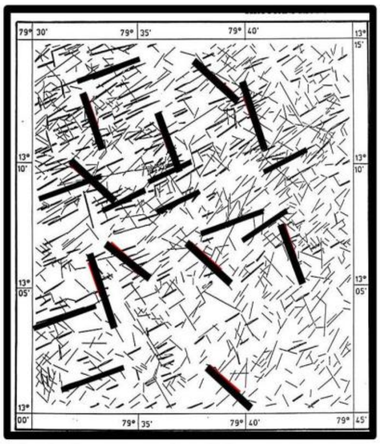

***Fig 8.** Fractures of transmissivity maxima (N20°-10° W & N60°-80° E)*

2.3.4 Fractures revealed by SRTM Shaded Relief Data

In addition to the above virtues of geomatics technology, the recently born Shuttle Radar Topographic Mission (SRTM) data which provides the elevation of the earth surface with 90M spatial resolution has proved its tremendous potentials in such fracture/lineament pattern mapping. Such SRTM produced ground elevation data can be beamed at two different elevations and azimuths with an imaginary light source using the image processing software, which will provide different types and shapes of shadows to the Earth surface depending upon the relief of the terrain and provide the shaded relief maps. Such shadows will enhance the relief and the fracture valleys. From such outputs, fine resolution fracture pattern maps can be prepared. One such shaded relief map prepared for parts of Kalrayan hills of Tamil Nadu is shown in Fig.9. This shows that N-S and NE-SW fractures are wide open and the WNW-ESE trending fractures are tight , hence obviously these different fractures will have differing ground water prospects .These N-S fracture systems again are the reflections of extension fractures related to the post collision tectonics of South India[26].Again , studies have inferred[26] that the NE-SW Precambrian dextral faults related to the origin of the Western and Eastern Ghat fold belts have transformed into sinistral faults during the above post collision tectonic phenomenon and such transformation would have closed the Precambrian faults in some segments and opened in some other sectors. Here in this case also, the NE-SW faults show wide open morphology confirming the above phenomenon of opening up of fractures during the repetitive tectonism. So such advanced tools need to be used to attain perfection in ground water targeting.

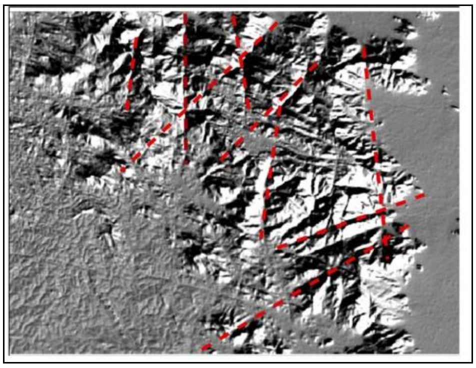

Fig.9: *Shaded relief output of Shuttle Radar Topographic Mission (SRTM) of part of Kalrayan hills, Tamilnadu showing wide open N-S and NE-SW fractures and the tight WNW-ESE fracture swarms*

2.3.5 3D Visualization of Fracture Systems

The 3D visualization of fracture systems is yet other unique option available with Remote Sensing and GIS technologies. This could be done by mapping the surficial fractures using Remote Sensing data and the multi depth fractures using GIS based digital elevation models of geophysical resistivity data.

The studies carried out for parts of northern Tamil Nadu [34] shows that geomatics involving remote sensing and GIS could be used as an effective tool for ground water prospecting and management. In the study, the surficial lineaments/ fractures were mapped using IRS 1A FCC and SRTM shaded relief data (Fig.10). Then with the help of over 900 geophysical resistivity data, Digital Elevation Models were generated from the apparent resistivity data of 50 meters (A) and 100 meters depths (B) (Fig.11). From the DEM, the resistivity valleys and breaks were interpreted as fractures for 50 & 100 M depths. Followingly, all these fractures interpreted at three levels viz; surface, 50 meters and 100 meters depths were integrated using Arc- GIS. From such an integration, the fractures were classified into three groups as surficial (1), surficial fractures extending up to 50M depth (2) and 1&2 extending upto 100M depth (3)(Fig.12). While the fracture group 3 is aligned in N-S in the western part, the same is found to have NE-SW to NNE-SSW orientations in the eastern part of the area. While the N-S group is the post collision extension fractures with wide open morpholohy, the NE-SW are the post collision sinistral strike slip faults [26] which would have opened up during the reactivation of Precambrian fractures during post collision tectonics as discussed above. So, the N-S faults and NE-SW faults can have better prospects for ground water. Further, the N-S faults of the western part of the area are seismogenically active [35] which adds further credentials and hence bound to have better prospects for ground water. Thus the fractures/ faults extending upto 100M depth do have better probabilities for ground water followed by fracture group 2. So all the lineaments/ fractures seen at the surface in the aerial and satellite data should not be ritually considered as water bearing and these need to be evaluated for their tectonic origin and also for depth extension utilizing the avenues available Geomatics.

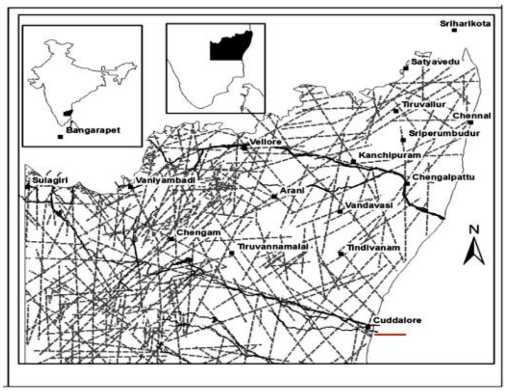

Fig.10: *Surface lineaments of Northern Tamilnadu interpreted from IRS 1-A and SRTM shaded relief data*

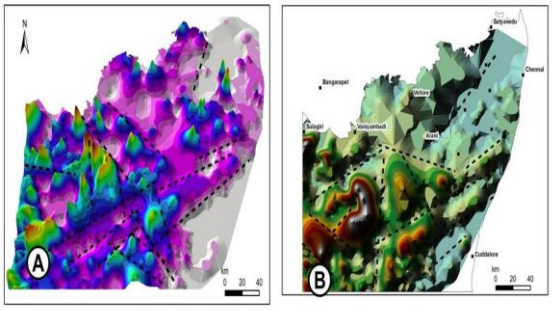

Fig-11A & B: *Geophysical resistivity DEM of 50M (A) and 100M (B) depths of Northern Tamilnadu showing fractures as resistivity valleys*

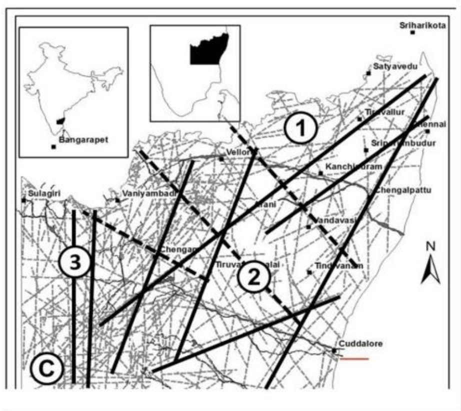

Fig. 12: *The integrated map of part of Northern Tamilnadu showing the surface fractures (1), surface fractures extending upto 50 m depth (2) and the fractures 1&2 extending upto 100m depth*

2.4 Mapping geomorphology and ground water

Similar to the fractured aquifer systems, geomorphology is yet another factor controlling the ground water systems. Lot of studies have been carried out including many national mission mode projects on Hydro geomorphic mapping by the National Remote Sensing Centre, Government of India, for Ground Water assessment. But most of the studies were confined to mapping of geomorphic landforms and qualitative appraisals on the ground water potentials of these landforms. But there are advanced virtues available with Geomatics not only in preparing fine resolution maps on landforms but also on their genesis and the morpho dynamic processes which only can give precise information on the ground water systems. For example, the geomorphology of Cauvery river system of Tiruchirappalli region provides a unique panorama and morphodynamic history (Fig: 13). The tributaries on the southern and northern banks of the river while show widely developed colluvial fills (1) indicating the dumping of unsorted mixture of loose sediments, the river Cauvery has developed wide upper (2) and lower (3) flood plains. Within the flood plains, there are back swamps (4) exhibiting dark grey tone (Fig. 13).

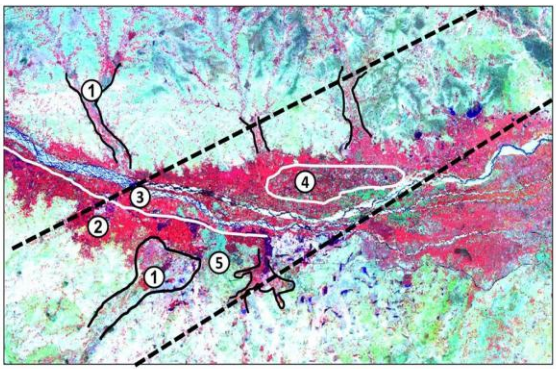

Fig 13. *IRS FCC showing colluvial fills (1), upper (2) & lower (3) Floodplains and backswamps (4) of Cauvery river,Tiruchirappalli (5),Tamilnadu*

Amongst these landforms, the lower flood plains have high ground water prospects, followed by the upper flood plains and by the colluvial fills. Where as in back swamps the ground water quality will be poor despite the adequate ground water potential because of the water logging prevailed since their origin. In addition, the two NE-SW trending sub parallel faults extend from Cumbum valley in the south west to Cuddalore- Pondicherry coast in the north east, along which there observed evidences for the ongoing land subsidence/ grabening [36]. Again , the occurrence of eyed drainages in number of stream and river segments in South India were found to indicate land subsidence[37], including the mega eyed drainage found in Cauvery river in between these NE-SW sub parallel faults (Fig.13). Such ongoing land subsidence only would have caused for the development of wide colluvial fills by the tributaries of Cauvery in Tiruchirappalli area.

Though, from the above, different grading could be given for the lower flood plains, upper flood plains and the colluvial fills, these three landforms occurring within the NE-SW faults bounded graben are expected to have higher ground water potentials than their counterparts occurring on either sides of the graben because the grabens can attract more ground water accumulation.

In IRS FCC, Mysore (Fig-14A) and Madavalli areas (Fig- 14 B) show similar scenario on the fluvial systems and the ground water conditions. In the Mysore area, Cauvery River shows broad eyed drainages along the crossing points of two NNE-SSW sub parallel lineaments (Fig. 14A). These eyed drainages as occur along the crossing points of the faults, and further the central entrapped land shows wider flood plains exhibiting thick red tone in FCC data, it shows that the entrapped land segment is subsiding along these faults and hence this zone has better ground water prospects.

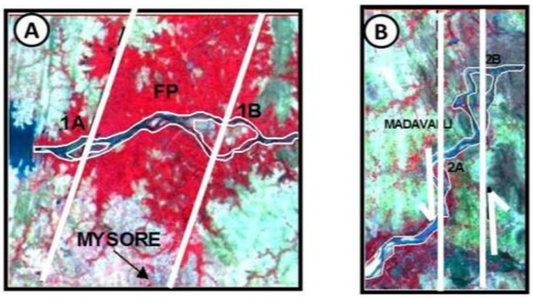

Fig 14*. IRS FCC (A) of Cauvery region showing eyed drainages (1A & 1B) in Cauvery river at the intersections of two NNE- SSW faults with wider flood plains (FP) in the entrapped land and (B) showing the dragged eyed drainages along similar N-S sinistral fault systems*

Similar eyed drainages found in Cauvery river in Madavalli area, Karnataka, (Fig: 14B) indicate land subsidence along the N-S sub parallel faults and hence better ground water prospects along them. But as these faults are laterally moving with sinistral strike slip movements, these faults check the ground water flow and thus the area west of these faults must have better ground water prospects, while the eastern parts would form a ground water shadow region. While these faults were inferred as extension faults related to post collision tectonics [26], studies have also attributed such N-S trending dextral and sinistral faults to N-S cymatogenic movements [38]. Thus these geomorphic and morphotectonic features need to be studied critically for scientifically strong ground water exploration, for which geomatics has got avenues as narrated above.

The migratory history of the rivers and the resultant occurrence of abandoned river courses are similarly yet other geomorphic landforms of ground water significance. Whenever a river has developed buried channels or the abandoned channels, only on one side of the mother channel, it will indicate the preferential migration of the mother channel. Under such scenario, the areas towards which the rivers are migrating will have better ground water prospects and the areas from where the rivers are migrating will have comparatively poor prospects. The Cauvery delta region stands as a testimony to these facts. Thus instead of simply mapping the fluvial geomorphic landforms, their genesis, geomorphic processes and the morphotectonic histories must be brought out which only can give precision to the ground water exploration. This is true with Denudational, tectonic, fluvial, coastal or Aeolian geomorphic provinces also. In all these, the geomatics technology comprising dominantly remote sensing and GIS.

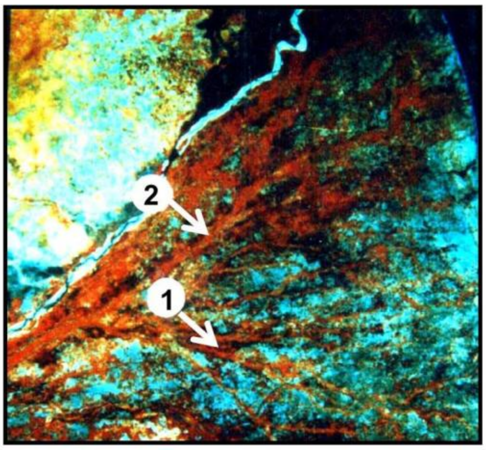

Fig 15. *IRS FCC data showing thin palaeo channels(1) in the south and the gradually wider channels (2) towards the north with the mother river Cauvery in the northern most extreme in Thanjavur delta*

3. Conclusions

Through the technologies have phenomenally grown in many areas, the hierarchy of issues faced by the development managers and the society are yet to be answered. The water resource is one such time demanding issue where science and technology is yet to be exploited. No doubt that good amount of studies has been carried out for the past over 6-7 decades or so, for solving the problems pertaining to water resources. Though the disproportionate population growth is the challenge, it has to be overcome by detailed scientific investigations to locate more water sources, especially the ground water, duly capitalizing the recent surges in technologies.

In this connection, the Geomatics technology comprising Remote Sensing and GIS has enormous potentials, but these are yet to be exploited deservingly. For example, some of the issues raised and the studies narrated in the paper are the significant hidden virtues of geomatics technology.

The Remote Sensing data with finer spectral and spatial resolution and the advanced image processing capabilities can give vital and finer information on the primary porosity of sedimentary rocks leading to their finer classification towards better understanding of their water potentials.

The remote sensing has exhaustive vistas in mapping the folded structures and their tectonic histories. Similarly, the fracture pattern mapping is currently done only to limited extent. The fractures/ lineaments/ faults, their origin, chronology, time transgressive dynamics, morphology, 3 D visualization, spatio-linear modeling etc. still remain as virgin and un explored areas , as explained with brief case studies here. In geomorphology too, we are to go a long way for water discoveries by exploiting the Geomatics. Infact information from all the above areas and domains must be taken into consideration in numerical modeling to get better results out of them.

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