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Spatial Pattern of Uncertainties: An Accuracy Assessment of the TIGER Files

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Abstract

This study discusses the ways how the positional accuracy of the TIGER files can be measured and spatially reported. Many people and companies use the address range of the TIGER files with the geocoding package within a Geographic Information Systems (GIS). However, the problem is that many people have little understanding of the inaccuracy of the TIGER files. This study examines the relationships between the distribution of inaccuracy and physical factors such as stream and urbanity. Next, the inaccuracy of the hydrography shape file of TIGER 2000 files is calculated by comparing it with the stream points data of United States Geological Survey (USGS)'s Geographic Names Information System. Finally, this study examines whether there are individual patterns in each spatial data by comparing the spatial pattern of the inaccuracies of the road and hydrography shape file.

Keywords: GIS, Spatial data quality, Inaccuracy, TIGER files

1. Introduction

As the TIGER files are used more widely, the necessity of making any inaccuracy of the TIGER files generally known increases. Because they are free, the TIGER files are widely used. Studies at the individual address level are now generally carried out. Improvements of the ability within GIS and the increase of storage capacity make this possible. However, compared with non-free data, the accuracy of TIGER files is of lesser quality. The TIGER files were built and have been continuously updated using a wide variety of source materials and techniques, including the GBF/DIME files, USGS 1:100,000-scale topographic maps, local and tribal maps, and enumerator updates of differing positional accuracy (O'Grady and Godwin, 2000). The varied update history has resulted in the inaccuracy of the TIGER files. Hence, an accuracy assessment of the TIGER files is necessary.

Ratliffe (2001) shows a practical example. He performed an accuracy assessment of individual address locations in the form of high-resolution geocoded point data, by comparison with both cadastral records that delineate the individual target properties, and areal units. These studies concentrated on assessing the accuracy of the spatial data by using computer-graphical methods. They applied the same standards for each region. They assumed that the imperfections of the spatial data resulted from only the carelessness of the mapmaker. But, they didn't provide a statistical trend or spatial pattern for the inaccuracies. To find the reasons for the inaccuracies, a statistical approach is required.

For the GIS researcher using the TIGER files, the spatial pattern and causes of the inaccuracies and the statistical mapping of the inaccuracy can help to eliminate the imperfections of their projects. Moreover, people who use the information derived from the TIGER files can interpret the information correctly.

The objectives of this study are to find the spatial pattern and reasons of the inaccuracies by statistical methods. If the reason or pattern is revealed, it is very helpful to minimize the distortion when people perform the project by using the TIGER files. Although the TIGER files are very popular data, many people have little understanding of the inaccuracy. Even people who do have an understanding often don't know why the TIGER files are inaccurate.

The definition of accuracy is the degree to which information on a map or in a digital database matches true or accepted values. There are four types of accuracy. These are positional, attribute, conceptual, and logical accuracy (Goodchild and Gopal, 1991). This study focuses on the positional accuracy and uses mainly the TIGER 2000 file of Erie County, New York State. The positional accuracy of a spatial object or a digital representation of a feature is the measurement of the difference between the apparent location of the feature as recorded in the databases, and the true location

(Goodchild and Hunter, 1997). For the reference data, Geography Data Technology, Inc. (GDT) Dynamap/2000 Street network data and United States Geological Survey (USGS)'s Geographic Names Information System data are used. And, for the tested data, the roads and hydrography shape file of the TIGER 2000 files are used. According to GDT(Note 1), they used much more points than any other non-free data like TIGER 2000 files. They are continuously updating more often with new information from the USPS and many private sources. Furthermore, because GDT also participated in creating TIGER files, it can be minimized the undesired errors. The errors can result from the different creation process of the reference data and tested data. This study is divided into two parts. One is the comparison of the road shape file and GDT Dynamap/2000 Street network data by using geocoding method. The other is the comparison of the hydrography shape file and the stream points data of USGS's Geographic Names Information System. By using ArcGIS Spatial Analyst and Geostatistical Analyst, the spatial patterns of the inaccuracies in each shape file are found. The results will show that there are individual spatial pattern of the inaccuracies in each spatial data.

2. Background

2.1 Data quality issues in GIS

The computing saying 'garbage in, garbage out' applies to GIS since if you put poor quality data into your program, the quality of your output will be poor. The results of analysis are only as good as the data put into the GIS (Heywood et al., 1998). Concern for geospatial data quality has grown rapidly because of increased data production by the private sector, increased use of GIS as a decision-support tool, and increased reliance on secondary data sources. These trends have affected the responsibilities of data producers and consumers for data quality. The producer was responsible for only sanctifying databases meeting official quality thresholds (Veregin, 1999). Heywood et al. (1998) mentioned that two issues are important in addressing quality and error issues: first, the terminology used for describing problems, and second, the sources, propagation and management of errors. However, Duckham (2002) noted that an obvious criticism about many spatial data quality standards and research is that these focus only on the storage, management and propagation of data quality information rather than how to use such information. Moreover, he insisted on the importance of the error-sensitive GIS. The error-sensitive GIS can be characterized as comprising three distinct stages: first, deciding upon the core data quality concepts; second, developing and implementing an error-sensitive data model based on these concepts; and third, developing interfaces able to deliver the error-sensitive services and functionality to users.

At this point, most people's perspectives are generally in sympathy on the importance of the concept of 'fitness for use' about the spatial data quality. Responsibility for assessing whether a database is proper for the needs of a particular application has shifted to the data users (Veregin, 1999). The data providers should supply enough information about the quality of a data set to help a data user make a proper decision in a particular situation (Chrisman, 1991). To meet "fitness for use," the producer's role has shifted to data quality documentation or "truth-in-labeling." According to the truth-in-labeling paradigm, errors are inevitable and the data quality problem results from incomplete knowledge of data limitations (Veregin, 1999). Nevertheless, the fitness for uses of a data set cannot be assessed entirely objectively. Rather than a simple 'yes' or 'no' answer, 'fit' or 'unfit', the degree of fitness for use will be qualified subjectively (Duckham, 2002). This results in various demands of the different users on data quality issues. Even a single organization or person may perform many of the different roles. In spite of the importance of 'fitness for use', previous methods focused only on quantitative factors such as how close the point is to the real point. This is insufficient to meet the requirements for 'fitness for use'. To meet the various demands of different users, detailed characteristics of the errors are considered necessary. The purpose of this paper is to find the spatial pattern of the inaccuracy and to provide the possibility to maximize fitness for use. This view corresponds to the view of the truth-in-labeling paradigm. The errors are not just a bad thing, but an inevitable thing. The errors are another attribute of the spatial data. Thus, the characteristics of the errors in spatial data should be clarified so that good quality results and output can be produced.

2.2 Measuring the positional accuracy of spatial data

An assessment of positional accuracy is related to the quality of the final product after all transformations. The lineage part of the quality report deals with the information on transformations. In the description of positional accuracy, the date of the test should be included. Additional attributes of spatial objects or a quality overlay (reliability diagram) is needed for variations in positional accuracy (U.S. Geological Survey, 1997).

Drummond (1995) divides the determination of positional accuracy into two steps. One is to measure the error generated by the systems. The other is to estimate the error generated by the systems. 'Measure' means to only consider the final positional information and compare the tested data to a known higher standard. This approach requires the availability of checkpoints whose x , y and z values are known. 'Estimate' needs the associated contributing standard deviation in each step of the processing.

Open GIS Consortium (1999) has developed Drummond's idea. Open GIS Consortium breaks down error estimation methods into five groups (Note2): professional estimate, computed estimate, compared to similar quality data, tested similar quality data, and tested sample actual data.

Practically, accuracy testing is performed in terms of horizontal accuracy and vertical accuracy. FGDC (2002) provides the standards for accuracy testing and verification. "Map testing should be performed within a fixed time period after delivery. Horizontal accuracy is tested by comparing the planimetric coordinates of well-defined ground points with coordinates of the same points from an independent source of higher accuracy. Vertical accuracy is tested by comparing the elevations of well-defined points with elevations of the same points as determined from a source of higher accuracy."

U.S. Geological Survey (1997) made a synthesis of the methods for positional accuracy in Spatial Data Transfer Standards (SDTS) into four categories: deductive estimate, internal evidence, comparison to source, and independent source of higher accuracy.

The concepts of the U.S. Geological Survey (1997) have a connection with the previous views. *Deductive estimate* includes not only the *Estimate* concept of Drummond (1995), but also the professional estimate and computed estimate of Open GIS Consortium (1999). 'Independent Source of Higher Accuracy' indicates comparison of data with high quality data. Thus, it includes the 'Measure' concept of Drummond (1995), the three comparison methods of Open GIS Consortium (1999), and the horizontal/ vertical accuracy concepts of FGDC (2002).

2.3 Previous analyses on TIGER/Line files

According to the U.S. Census Bureau, TIGER 2000 Line files are designed to show only the relative positions of elements. In the 2000 TIGER/Line files technical documentation, the following statements appear about positional accuracy:

"Coordinates in the TIGER/Line files are in decimal degree and have six implied decimal places. The positional accuracy of these coordinates is not as great as the six decimal places suggest. The positional accuracy varies with the source materials used, but at best meets the established National Map Accuracy standards (approximately +/- 167 feet) where 1:100,000 scale maps from the USGS are the source. The U.S. Census Bureau cannot specify the accuracy of feature updates added by its field staff or of features derived from the GBF/DIME-Files or other map or digital sources."

Previous analyses on TIGER/Line files have focused on comparing it with an 'independent source of higher accuracy'. Zent (1996) compared the U.S. Census Bureau's TIGER/Line files with the U.S. Geological Survey's Digital Line Graph (DLG) files. The relative accuracy of TIGER/Line files and DLG were tested by using the content of USGS 1:12,000 scale digital orthophoto quarter-quadrangle backdrop images as the reference data for dataset accuracy. The results demonstrated that TIGER/Line files, in 4 out of the 6 study areas, were found to be more positionally accurate in their coordinates' location than the DLG dataset intersections.

Ratcliffe (2001) tested a TIGER-type geocoding process by using point-in-polygon methods. A study of over 20,000 addresses in Sydney, Australia showed that 5-7.5% of addresses may be misallocated to census tracts and more than 50% may be given coordinates within the land parcel of a different property.

After reviewing the positional accuracy information of TIGER/Line files, O'Grady et al. (2000) stated three needs to improve the positional accuracy of TIGER: internal needs, a desire to use local and tribal files for updates, and a desire to facilitate data exchange. Here, internal needs are related to a technological requirement. For example, Global Positioning Systems (GPS) technology is considered a powerful way to capture new coordinates for existing anchor points.

According to Liadis (2000), the Geography Division (GEO) of the U.S. Census Bureau uses the GPS to assess the spatial accuracy of the TIGER data base in its preparation for TIGER modernization. A tool called the GPS TIGER Accuracy Analysis Tool (GTAAT) is developed to evaluate the spatial accuracy of attributes derived from a variety of operations and sources. The GTAAT calculates the distance and azimuth difference between the GPS collected point and the equivalent TIGER 0-cell (point). By utilizing the GTAAT, it was revealed that there was a large variance in the mean distance difference from TIGER to ground truth based on the source code. It resulted from an inherent positional accuracy of each data source. Thus, the GEO concluded that the current accuracy of point and linear features in the TIGER system limits the ability to exchange data digitally through partnerships.

Moreover, O'Grady (2001) introduced a DOQ (Digital Orthophoto Quadrangles) test method to improve the TIGER. She stated that there are two components of TIGER improvement: Updating the data base by adding new features and spatially enhancing existing features. GPS technology is useful to test the updated TIGER data base, while, improving the positional accuracy of and spatially enhancing TIGER is tested by the DOQ. The DOQ test is composed of two parts. One is to capture the coordinates of certain TIGER feature intersections called "anchor points". The other is to transform all TIGER coordinates using the newly collected DOQ anchor point coordinate data.

To sum up, previous analyses on TIGER/Line files show that everyone agrees that the inaccuracy problem of TIGER/Line files limits the ability to exchange data. Thus they attempt to test TIGER/Line files with various methods

and reference data. However, there are no attempts to maximize current fitness to use with detailed information of the inaccuracies. Therefore, the spatial characteristics of the inaccuracies are considered necessary for that.

3. Study area

According to Erie County Works (Note3), Erie County is a metropolitan area located in the western part of New York State. It covers 1,058 square miles. The County is bounded by Lake Erie to the west, Niagara County and Canada to the north, Genesee County and Wyoming County to the east, and Cattaraugus and Chautauqua Counties to the south. "More than half of the population in both countries, as well as 52 percent of the personal income (\$1.4 trillion) created by the United States and Canada are within 500 miles of Erie County. In addition, three-quarters of Canada's manufacturing activity and 55 percent of the United States' manufacturing activity fall within that radius. Located within the County are three cities and 25 towns, including the City of Buffalo, the second largest city in New York State." The land use pattern has led to expansion in the suburban towns and a mixed pattern of stability, decline, and redevelopment in the City of Buffalo. The northern towns have grown relatively more. The eastern towns are beginning to develop, while the southern towns are developing at a slower pace.

4. Data

4.1 TIGER files

This study uses mainly the roads and hydrography shape file of the TIGER 2000 files. According to the U.S. Census Bureau (Note 4), most information in TIGER outside the urban centers was derived from the USGS 1:100,000-scale digital line graphs, which were vectorized from the digital scanning of the original artwork. The original artwork was in Universal Transverse Mercator (UTM) projection. After the map sheets were scanned, the coordinates were transformed from UTM into projectionless geographic coordinates of latitude and longitude. For most urban centers, the information in TIGER was derived from the GBF/DIME files produced for the 1980 census. There were a variety of other sources used in creating the Census TIGER data base. The features from those sources also were stored as latitude and longitude coordinates. Subsequent updates to the Census TIGER data base also came from a variety of sources, including paper maps annotated in the field and subsequently digitized without rigorous adherence to a projection or coordinate system.

4.2 Dynamap/2000 Street network data

This data is used for testing the accuracy of the road shape file of TIGER 2000 files. Geography Data Technology (GDT), Inc. built the Dynamap/2000 Street network data. According to GDT (Note 5), the boundary layers of the Dynamap/2000 Street network data, except for ZIPs, have not been generalized. Every polygon (area surrounded by boundary segments) and every feature (geographic unit formed by one or more polygons) has as many points as are required to draw its shape accurately. Hence, this data was used for the reference data. The version of the Dynamap/2000 files used in this study is 11.2 (July 2001). The scale of this data is 1:24,000. All coordinates are based on the 1983 North American Datum (NAD83), like the TIGER 2000 files.

4.3 Address data

This data is used for performing geocoding with the road shape file and GDT Dynamap/2000 street network data. For statistical analysis, randomly and independently selected address data is needed. To perform geocoding, the address data of the schools in Erie County was used. Compared with other kinds of data such as hotels, restaurants, and so on, schools are evenly distributed and each community has schools. The school address data is acquired from National Center for Education Statistics (NCES) website (Note 6).

4.4 Geographic Names Information System

This data is used for testing the accuracy of the hydrography shape file of TIGER 2000 files. According to the USGS (United States Geological Survey) (Note 7), "The Federally recognized name of each feature described in the data base is identified, and references are made to a feature's location by State, county, and geographic coordinates." In this study, the stream points data in Erie County, New York is used. According to the metadata, the accuracy of these data is based on the use of source graphics which are compiled to meet National Map Accuracy Standards. The main sources are 1:24,000-scale topographic maps, records of the U.S. BGN, and U.S. Forest Services 1:24,000-scale topographic maps. Because the TIGER files are based on 1:100,000-scale topographic map, these data can be used as more accurate reference data.

5. Methodology

5.1 Test of the road shape file of TIGER 2000 files

The purpose of this part is to test whether there is spatial pattern of the inaccuracies and whether there is a relationship between these spatial patterns and physical factors.

5.1.1 Data preparation

Using the road shape file of TIGER 2000 files as the tested data and the Dynamap/2000 Street network data as the reference data, geocoding is performed. The output of the geocoding is x, y coordinates. The street files option in

ArcGIS is checked. In geocoding, the suitable line segment is selected by using the target address, and then a location is interpolated between the 'from node' and the 'to node'.

Ratcliffe (2001) showed the importance of the offset in geocoding. Moreover, he mentioned the potential problems with the geocoding. The problems are out-of-date street directories, abbreviations or misspelling, local name variations, address duplications, non-existent address, line simplification, noise in the address file, geocoding non-address locations, geocoding imprecision, and ambiguous or vague addresses. To overcome these problems, addresses that don't score 100 or match a unique location are ruled out. Furthermore, by using statistical methods such as leverage values, outliers are excluded.

5.1.2 Inaccuracy mapping and finding the reasons of the inaccuracy

After the geocoding is performed, the distances between the coordinates from the tested and reference data are calculated. There are many ways to calculate the distance between two points on the earth's surface, defined by their latitude and longitude. In this study, the Great Circle Distance based on Spherical trigonometry is used. This method assumes that 1 minute of arc is 1 nautical mile and 1 nautical mile is 1.111 miles. The formula (Note 8) is as shown below.

$$D = 1.111 * 60 * \text{ARCOS} (\text{SIN} (L1) * \text{SIN} (L2) + \text{COS} (L1) * \text{COS} (L2) * \text{COS} (DG)) \quad (1)$$

L1 = latitude at the first point (degrees)

L2 = latitude at the second point (degrees)

DG = longitude of the second point minus longitude of the first point (degrees)

D = computed distance (mile)

The distances with the addresses are divided into 5 categories by natural break. Then, these are mapped within ArcGIS.

Here, to find the spatial pattern of these mapped points, interpolation is performed. Interpolation means to predict values at locations where data has not been observed. To do that, Kriging was used in the Geostatistical Analyst in ArcGIS is used. According to Johnston et al. (2001), the kriging is a statistical interpolation method that uses data from a single data type to predict values of that same type at unsampled locations. After looking over the result of the interpolation, the independent variables are selected for the distances as the dependent variables. For example, the length of the line and the width of the line can be independent variables for the inaccuracies. Finally, correlation values between independent variables and the distances are calculated.

5.2 Test of the hydrography shape file of TIGER 2000 files

The purpose of this part is to examine whether there is an individual spatial pattern of the inaccuracies in each spatial data set by testing another spatial data set.

5.2.1 Data preparation

The stream points data in Erie County, New York are obtained by querying the Geographic Names Information System (GNIS) online database. The fields in the result table are feature name, state, county, type such as stream, latitude, longitude, and related USGS 7.5' map. The number of points is 73.

These points don't have a specific pattern. In ArcGIS, the point data should have the decimal degree coordinates to create point coverage. Thus, in Microsoft Excel, the latitude and longitude of the stream points are converted to decimal degrees. By using converted decimal degrees, the point coverage is created. The hydrography shape file of TIGER 2000 files is also converted to arc coverage by utilizing ArcToolbox in ArcGIS. To calculate the distance between each stream points and hydrography shape file, these two data should be coverage data formats that have a topology.

5.2.2 Inaccuracy mapping and finding the reasons of the inaccuracy

The distance between the stream points and the hydrography shape file is calculated by using ArcToolbox's near function in the Analysis category. The distances are divided into five categories by natural break. Then, ArcGIS performed mapping with this distance. To find the spatial pattern of these mapped points, interpolation is performed. To do that, the Geostatistical Analyst in ArcGIS is used. In the Geostatistical Analyst, the kriging method is selected.

6. Results

6.1 Inaccuracy of the road shape file

For the geocoding, the addresses of the 235 public schools in Erie County, New York are used. After the points that don't score 100 or match a unique location are ruled out, 187 points remain. When the distances between the coordinates that come from the tested and reference data are calculated, the points whose distance is more than 1 mile are regarded as outliers. Now, 168 points remain (Figure 1). These 168 points are used for the comparison of the reference data and target data.

With x, y coordinates and the value of the distances, the Geostatistical Analyst creates the interpolation map based on the kriging method to show the spatial pattern of inaccuracies (Figure 2). The dark area is the area less accurate relatively. At this point, the spatial pattern appears. The map shows the less accurate area in rural area.

For the pilot study, urbanity and stream are selected as potential reasons for the inaccuracies. These are the independent variables. Any other factors can be the reasons. The dependent variable is distance. By using the Statistical Package for the Social Sciences (SPSS), the correlation values are calculated between the independent variables and dependent variable. By using the selection by location function, the points in the urban area are selected and scored 1. The other points scored 0 (Figure 3). It means that the points in the dark area in figure 3 are scored 1. Moreover, buffering makes it possible for the points within 1 mile from the stream to score 1. The other points scored 0 (Figure 4). And then, SPSS calculated the value of the correlations between the distances and these scores (Table 1 and 2).

In table 1, the significant (0.048) correlation value (-0.126) means that the points in the urban area are closer to the referencing points than outside the urban area. As mentioned, most information in TIGER outside the urban centers was derived from the USGS 1:100,000-scale digital line graphs, which were vectorized from the digital scanning of the original artwork. For most urban centers, the information in TIGER was derived from the GBF/DIME files produced for the 1980 census. This means there is basically a difference between the urban centers area and the area outside the urban centers. In table 2, the significant (0.037) correlation value (0.105) means that the points near the stream are less accurate than of those far from the stream. The roads near the stream cannot maintain a straight line. Because the stream is changeable, the shape of the roads near the stream is also changeable. When interpreting the results, the significance value is a little bit high. However, because the purpose of this study is not calculating an accurate spatial pattern of inaccuracies, but checking the existence of spatial pattern, it can be neglected.

6.2 Inaccuracy of the hydrography shape file

From USGS's Geographic Names Information System database, the coordinates of 73 stream points in Erie County, New York are obtained. After creating point coverage in ArcGIS, it can be seen that these points are distributed randomly. Thus, this data is proper for performing mapping of the inaccuracy and looking at the spatial pattern of the inaccuracies. Basically, these points should be placed on the hydrography shape line, but they are not. The distances between the stream points and hydrography shape lines are calculated by the near function in ArcToolbox. These distances indicate the degree of inaccuracies for each stream points. The results show that the distances are not uniform and showing spatial pattern of inaccuracies (Figure 5).

To see the spatial pattern of inaccuracies well, mapping of the inaccuracies is done by using the Geostatistical Analyst in ArcGIS. Interpolation is performed by kriging methods same as in the case of the road shape file.

The result of mapping shows that there is a spatial pattern to the inaccuracies (Figure 6). The dark area is the area that has relatively high inaccuracy. In this study, the dark areas are located near the downstream. Because the width of the stream is wider than the upper stream, it seems more difficult for the hydrography shape line to be accurately placed on the real center line of the stream.

7. Discussion and future work

In conclusion, it is certain that there is a spatial pattern and specific reasons for the inaccuracies about the TIGER 2000 files. The inaccuracies of the road shape file of the TIGER 2000 files are related to the urbanity and the distance from the stream line. The inaccuracies of the hydrology shape file are related to the width of the stream. Moreover, it is revealed that the spatial pattern of the inaccuracy exists individually in each spatial data set. After the interpolation of the inaccuracies of the road and hydrology shape file is performed, it can be easily observed that there is a big difference between the results of the interpolation. Thus, the spatial pattern of the inaccuracies in the spatial data set should be examined separately. Each spatial data have their reasons for the inaccuracies.

To get more significant correlation values, more factors should be tested as independent variables. In this study, only the urbanity, the distances from the stream line and the widths of the stream are considered reasons for the inaccuracies. For more correct estimates, more factors such as the elevation, the width of the road, and so on should be considered. The presence of the correlation between the factors also should be checked carefully.

Areas that have different characteristics should also be tested. Erie County is a relatively flat area. Thus, it is necessary that the area where the change of elevation is severe should be tested. The area where there is no stream, such as a desert, can have the different spatial pattern of the inaccuracies unlike the area where there are many streams.

Digital spatial data cannot involve everything in the real world. Thus, the inaccuracy of spatial data is absolutely natural. The only thing to do is to recognize the characteristics of the inaccuracy as another attribute of spatial data. For 'fitness to use', the metadata should report not only the general accuracy of data, but also the spatial pattern of the inaccuracy. If the users know the spatial characteristics of the inaccuracies in the spatial data set, they can cope with the situation of the inaccuracies.

In this study, only two shape files of the TIGER 2000 files are tested. The other files of the TIGER 2000 files should be tested. Moreover, the subjects of the study about the spatial characteristics of the inaccuracies involve not only vector data, also field-like data in raster format such as DEM. In future studies, these data should be tested. The ultimate purpose of these kinds of studies is to maximize the quality of the data and to help the user to use an imperfect spatial data set properly. Thus, the way to systematically increase the quality of the data with the spatial characteristics of the inaccuracies should be developed. Furthermore, the standard to avoid improper use of the spatial data which results from ignorance about the spatial characteristics of the inaccuracies remains for the further research.

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Notes

- Note 1. Dynamap/2000 user manual (http://www.geographynetwork.com/data/download/gdt/gdt_dynamap_gn.pdf)
- Note 2. Open GIS Consortium, 1999. The *OpenGIS Abstract Specification*. Topic 9. Quality: 17.
- Note 3. Erie County Overview (<http://www.erie.gov/overview/>)
- Note 4. TIGER/Line Metadata (<http://www.census.gov/geo/www/tlmetadata/metadata.html>)
- Note 5. Dynamap/2000 user manual (http://www.geographynetwork.com/data/download/gdt/gdt_dynamap_gn.pdf)
- Note 6. [Http://nces.ed.gov/](http://nces.ed.gov/)
- Note 7. [Http://geonames.usgs.gov/gnishome.html](http://geonames.usgs.gov/gnishome.html)
- Note 8. Source: Geoscience Australia (<http://www.auslig.gov.au/geodesy/datums/distance.htm>)

Table 1. Correlation value between the inaccuracy of the road and urbanity

Correlations

		Distance	Urban
Distance	Pearson Correlation	1	- 0.126
	Sig.(2-tailed)	N/A	0.048
	N	168	168
Urban	Pearson Correlation	- 0.126	1
	Sig.(2-tailed)	0.048	N/A
	N	168	168

Table 2. Correlation value between the inaccuracy of the road and stream

Correlations

		Distance	Stream
Distance	Pearson Correlation	1	0.105
	Sig.(2-tailed)	N/A	0.037
	N	168	168
Stream	Pearson Correlation	0.105	1
	Sig.(2-tailed)	0.037	N/A
	N	168	168

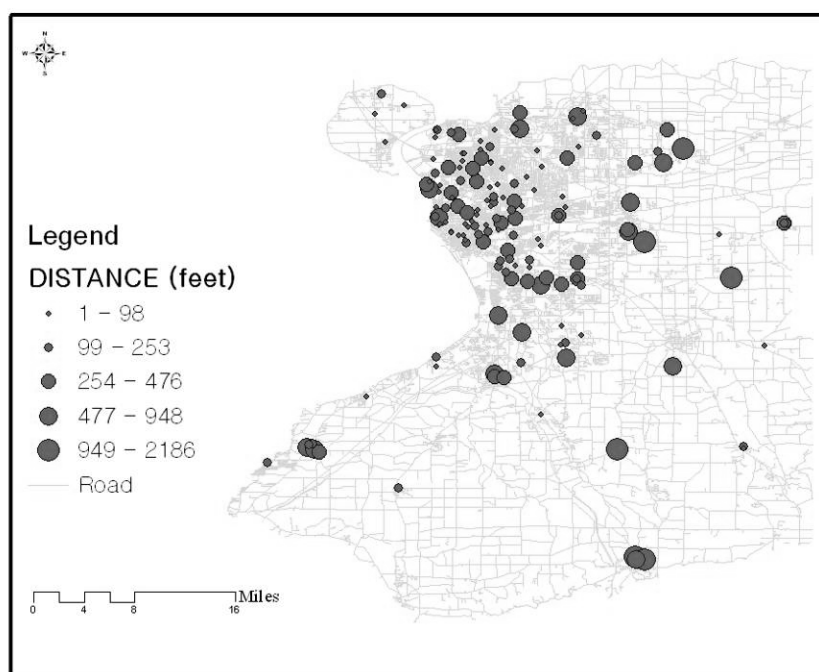


Figure 1. Inaccuracies of the road shape file of TIGER 2000 files based on the distances between geocoding results of the schools

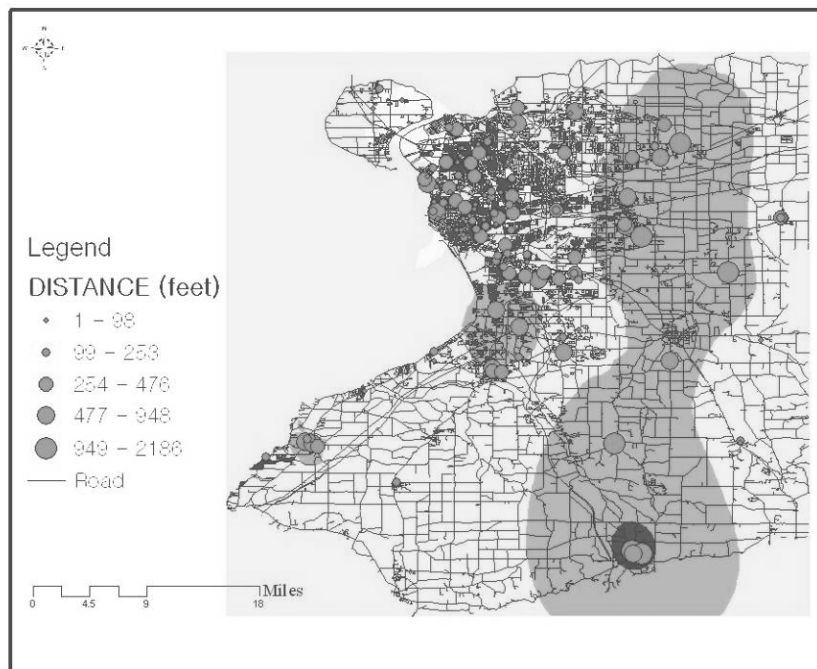


Figure 2. Mapping the inaccuracies of the road shape file by kriging methods

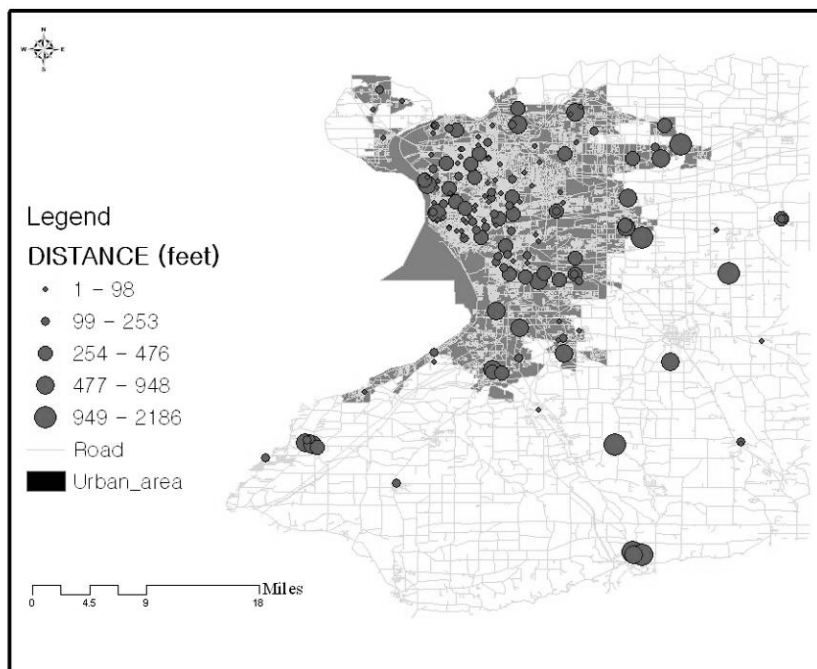


Figure 3. Factor 1 for the inaccuracies of the road shape file: Urbanity

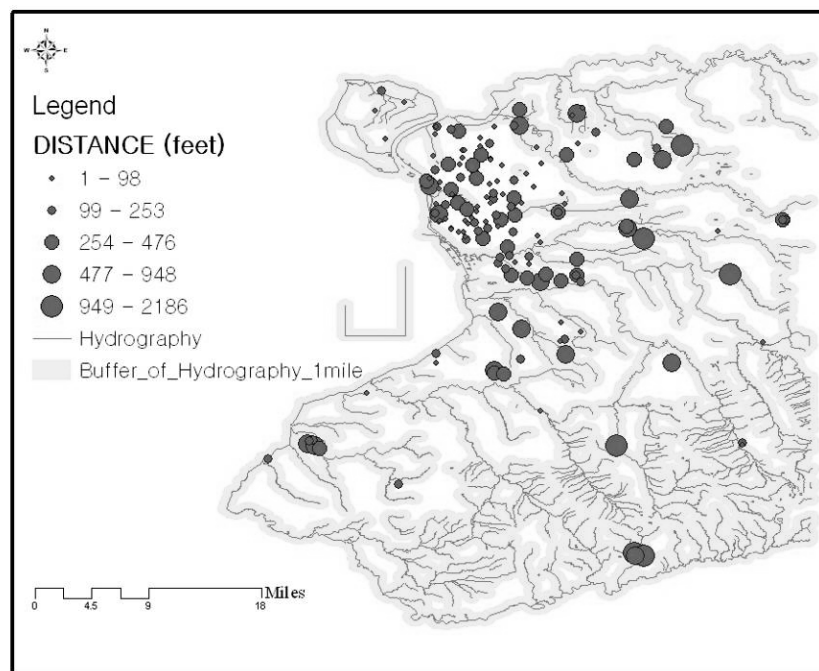


Figure 4. Factor 2 for the inaccuracies of the road shape file: Stream

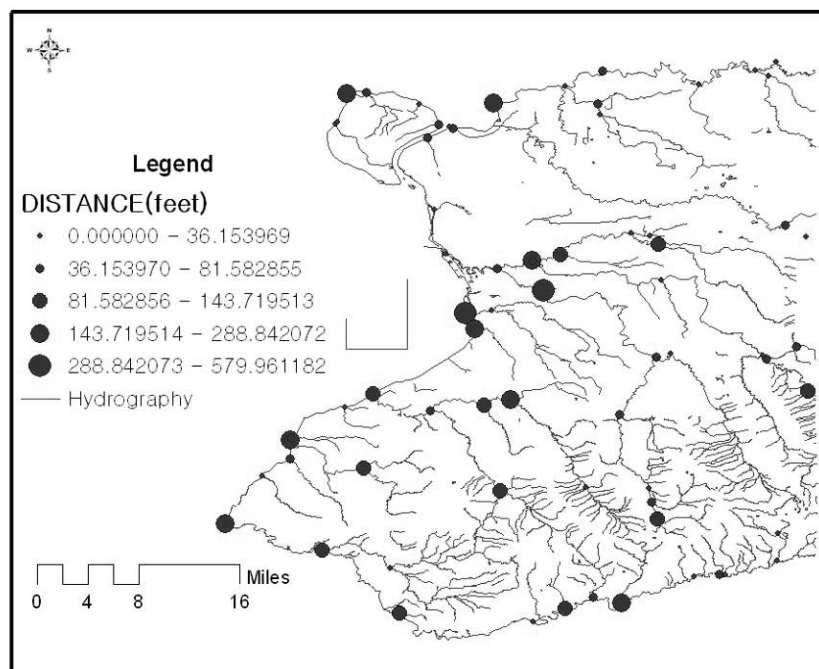


Figure 5. Inaccuracies of the hydrography shape file of TIGER 2000 files

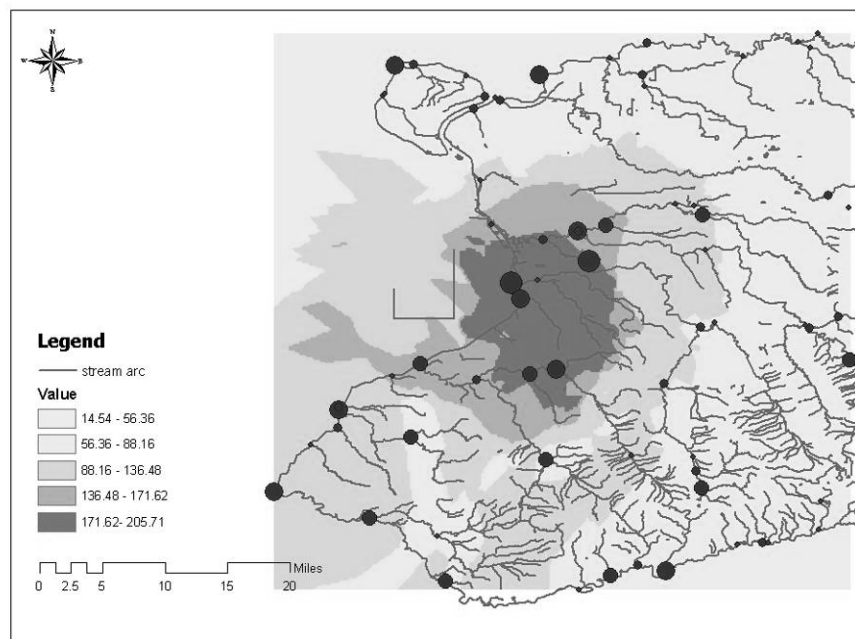


Figure 6. Mapping the inaccuracies of the hydrography shape file by kriging methods



New Method for Identification of Blue Topaz —An Application of Cathodoluminescence(CL)

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Abstract

Blue colored topaz is the most commercialized gemstone worldwide at present. Very rare in nature, most of these topazes are treated by laboratory irradiation with gamma ray, neutron or electron, or in combination with them ever since more than 30 years ago. Knowledge about the origin of the blue color in topazes is not well understood, and a method to identify blue topaz nondestructively is a worldwide problem.

In this research, the tested samples were natural blue, colorless topazes and irradiated blue topazes which were firstly tested by using UV lamp ($\lambda=365, 254\text{nm}$). Results showed that the UV fluorescence of the natural blue topazes ranged from very strong to very weak, while those of the irradiated blue topazes were always very weak or even no fluorescence. Based on the UV fluorescence testing, their cathodoluminescence(CL) characteristics were studied emphasisly by using CL-2 cathodoluminescence spectroscope produced by Gemmological Institute of CUG and USB2000 CCD multi-channel spectroscope produced by Ocean Optics, U.S. For this study, CL spectra was acquired at an accelerating voltage of 9.5~10.5 kV, a 0.95~1.05 mA beam current, and entrance and exit slit widths of 4 mm. Results indicated that the maximum of the broad emission bands of all the topazes were always at approximately 500 nm with a side band at approximately 492 nm, and CL of natural blue topazes was the strongest (about 40~50 counts), followed by the natural colorless topazes (about 20~30 counts) and the irradiated blue topazes (less than 15 counts), only 1/3 of the natural blue topazes. Therefore, CL characteristics could be used to separate the natural blue topaz from the irradiated blue topazes rapidly and nondestructively.

Keywords: CL, Natural blue topaz, Irradiated blue topazes, Spectra

1. Introduction

Blue topaz is usually sky blue, with little grey or green hue, similar to aquamarine and its color is pretty. Natural blue topaz is rare, and more than 95% blue topazes in the world are produced in the pegmatite of Minas Gerais in Brazil, near to Silva Rodriguez City (Yukihara, 1999; Gatta, 2006). However, colorless topazes could be greatly available in numerous places, as well as Guangdong province, China. Accordingly, a host of blue topazes in the market are produced using colorless or light topazes through irradiation treatment to change the color. Currently, there are three routine irradiation inducing coloration methods (Leala, 2007; Krambrock, 2007; Silva, 2005), viz. ^{60}Co gamma rays, electron accelerator (charged particles) and nuclear reactor (fast neutron). Topazes treated by gamma rays usually are sky blue or American blue with light color; Topazes by neutron irradiation are London blue with dark color; while those by electron irradiation are Swiss blue with gorgeous and pretty color and less residual radiation, respectively (Figure 1).

Topazes processed by irradiation treatment inducing coloration were homogeneous with stable color, no mottling and color band (Gatta, 2006). They could be preserved for a long period at a high or low temperature, and when exposed to acid, alkali and salt solutions, they were immune to interference. Physical and chemical properties of topazes after and

before irradiation inducing coloration treatment such as hardness, density, refractive index, and birefringence and so on almost coincide with natural topazes excluding color (Table 1).

Although identification methods such as infrared spectroscopy, thermoluminescence and so on were recommended by some researchers (Krambrock, 2007; Silva, 2005), due to the complexity of performance, high temperature of experiment and great damages to samples, the efficacious method to identify blue topazes by irradiation treatment is not available at present. How to differentiate blue topazes in nature or processed by irradiation treatment promptly, conveniently and exactly became a difficulty to gemstone identification currently. In the present paper, CL characteristics of blue topazes in nature or processed by irradiation treatment were studied emphasisly in order to seek an efficacious way to identify blue topazes nondestructively.

2. Experimental samples and methods

Samples for testing included three types: natural blue topaz (9), natural colorless topaz (8) and blue topaz after irradiation treatment (20). Natural blue topazes were produced in Friedi Mine in Brazil. Among topazes after irradiation treatment, 1 was Swiss blue irradiated by electron and others were London blue by neutron.

Topazes were measured by UV lamp used for standard identification of gemstone at the long wavelength of 365nm and the short wavelength of 254nm, and results showed that UV fluorescence of natural topazes varied often: UV fluorescence of some topazes, especially dark blue was strong, green-yellow of middle intensity at long wavelength and weak intensity at short wavelength; UV fluorescence of some blue or colorless samples were weak, light cyan at long wavelength, weak or even no fluorescence at short wavelength. UV fluorescence of blue topazes by irradiation treatment was cyan and weak at long wavelength, while that of Swiss blue samples was stronger. All topazes for testing by irradiation treatment at the short wavelength of UV had no visible fluorescence.

Based on the UV fluorescence testing, their CL images and spectra were investigated by CL-2 cathodoluminescence spectroscope produced by Gemmological Institute of CUG and USB2000 CCD multi-channel spectroscope produced by Ocean Optics, U.S. For this study, CL spectra were acquired at an accelerating voltage of 9.5~10.5 kV, a 0.95~1.05 mA beam current, and entrance and exit slit widths of 4 mm or so) Results were listed in Table 2.

3. CL characteristics of topazes

CL has been used for a long time in petrographic studies to determine the provenance of mineral grains or to distinguish generations of growth within minerals. Recently, CL detectors have been attached to scanning electron microprobes allowing a better control of the electron beam flux and general instrument stability, and permitting higher magnification and spectrometric measurements in the UV and visible ranges. Its basic principle was depicted as follows: high speed electrons with high energy resulting from cathode ray tube converged in the surface of samples, and due to higher energy of electron beam than UV, its electrical excitability was stronger, which facilitated many mineral samples with no UV luminescence have obvious CL. (Yuan, 2005, Barbar, 2001; Lindblom, 2003).

Observations indicated that CL color of different type topazes was similar, and all showed blue fluorescence, but topazes were significantly different in luminous intensity and threshold excitation voltage.

3.1 Luminous intensity characteristics

Under the condition of a high voltage of 9.5~10.5 kV, a 0.95~1.05 mA beam current, CL of natural blue topazes (Fig. 3a) was the strongest with blue light of middle brightness; natural colorless topazes (Fig. 3b) followed with blue light of medium weak brightness; CL of irradiated blue topazes (Fig.3c) was the weakest with weak blue light, only in the sections of edges and corners centralized bombarded by electrons.

3.2 Spectra characteristics

A. CL spectra of natural and irradiated topazes were broad and gentle curves, and the main wavelength of peak were at 492-500nm, which was the reason that topazes possess blue fluorescence. Peak shape and position of natural topazes was approximately identical to irradiated ones.

B. CL of natural blue topaz was the strongest with an intensity of about 40~50 counts, followed by the natural colorless topaz (about 20~30 counts) and the irradiated blue topaz(less than 15 counts), only 1/3 of the natural blue topaz. (Figure 4 and Table 2).

3.3 Threshold excitation voltage characteristics

Through the testing, it was noted that by the bombarding of electron beams, natural topazes (whether blue or colorless) irradiated easily, with a threshold excitation voltage appearing fluorescence at only 4-5kV; While threshold excitation voltage of irradiated topazes was obviously higher, at 6-7kv. Such threshold difference, as well as CL intensity, all suggested that the luminescence property of natural topazes was obviously stronger than that of irradiated ones, which indicated that CL mechanisms of natural topazes were quite different from irradiated ones.

4. Identification flow of blue topaz

- 4.1 Prepare standard samples of a natural colorless (blue) and an irradiated blue topaz;
- 4.2 Compare UV fluorescence intensity of unknown samples with that of standard samples, if UV fluorescence of unknown sample is strong, it is natural blue topaz; If not, a further CL test is necessary;
- 4.3 Put the natural colorless (blue) standard topaz and the blue topaz for checking into sample chamber of gemstone cathodoluminescence spectroscopy, and compare their CL intensity. Under the condition of a high voltage of 9.5~10.5 kV, a 0.95~1.05 mA beam current, if its CL intensity is equivalent to natural blue or colorless topaz, the blue topaz for checking is natural blue topaz, otherwise it is irradiated topaz (Figure 5). If CL spectra of topazes are available, the result will be more accurate.

5. Discussions

Our observations indicated that CL of natural blue topazes was markedly higher than that of irradiated blue ones, and UV fluorescence also showed this trend (Tarashchan, 2006). What was the cause for the difference of such luminescence intensity?

Topaz is an aluminum fluorosilicate with chemical formula $\text{Al}_2\text{SiO}_4(\text{F},\text{OH})_2$, in which OH^- may substitute for up to 30mol% of the F^- . It crystallizes in the orthorhombic space group $Pbnm$ (D^{16}_{2h}) with four molecules per unit cell, but the OH/F substitution turns its symmetry into triclinic (P1) (Pinheiro, 2002, PP.104-301). In the lattice of topaz, a hexagonal close packed structure of O^{2-} and F^- ions in ABAC sequence in which the small Al^{3+} and Si^{4+} cations are located interstitially between the layers, respectively, and trace elements such as Cr, Fe, Ti, V, and so on could replace Al^{3+} of the lattice in the form of isomorphism (Yukihara, 1999; Leala, 2007; Krambrock, 2007; Silva, 2005). According to the Electron Paramagnetic Resonance (EPR) study on the natural blue, colorless topaz and irradiated topaz by Dickinson and Moore, EPR features confirmed that impurities in natural blue or colorless topaz was Fe^{3+} in the octahedral or interstitial position and defect centre was X hole center; F hole center only existed in blue topazes, viz. color center of inducing blue which was in the O^{2-} of Si-O tetrahedron surrounded by six F^- ions in the same crystal surface (010).

During the process of topazes irradiated by the high speed electrons resulting from CL, hole center precursor, O^{2-} possessed conjugated electrons radiate away when bombarded by high energy particles. Most electrons emitted by O^{2-} were used for forming F color center, but denier electrons were captured by impurities Fe^{3+} to form Fe^{2+} . Fe^{2+} was the most efficacious fluorescence quencher and could greatly attenuate CL effect. Accordingly, it is not tough to elucidate that CL intensity of natural blue topazes was higher than that of irradiated ones.

6. Conclusions

- 6.1 Observations indicated that CL of topazes was usually weak with same color, but CL intensity of natural blue topazes was markedly higher than that of irradiated ones. This difference could be easily recognized in Gemstone cathodoluminescence spectroscopy. Especially when these two kinds of topaz were undertaken CL comparison, we could obtain more accurate and effective results.
- 6.2 Results of CL spectra determination indicated that CL relative intensity of natural blue topazes was 2 times higher than that of irradiated ones. Intensity difference was quite obvious.
- 6.3 Irradiated blue topaz usually possessed no or weak UV fluorescence, but some natural blue topazes had strong UV fluorescence, which could be used as a quite convenient and efficacious identification method.

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Table 1. Property variation of topazes after and before irradiation treatment

Property category	Test method or apparatus	Property change before or after irradiation
Chemical composition	Chemical analysis	Aluminosilicate, no change
Crystal Structure	D-max3X ray powder diffraction	Orthorhombic system D_{2h}^{16} , no change
valence bond	PE-983Ginfrared spectrophotometer	Infrared 3644, 1004 cm^{-1} absorption spectrum, no change
relative density	Hydrostatic weighing method	3.56, no change
Hardness	Mohs hardness scale	8.0, no change
Refractive index	immersion method	$N_g=1.624$ $N_p=1.615$, no change

Table 2. Testing results of some samples

Serial number	Sample characteristics			cathodoluminescence(CL)			UV fluorescence	
	Property	color	Cutting style	Excitation voltage /KV	Relative intensity/ counts	Peak/nm	Long wavelength	Short wavelength
1	Natural	Light blue	Ellipse	5	20~25	496	Very weak	No
2	Natural	Light blue	Rough stone	5	50~55	492	Very weak	Very weak
3	Natural	Light blue	Rough stone	5	30~35	514	Middle	Weak
4	Natural	Light blue	Emerald	5	85~90	497	No	No
5	Natural	Light blue	Rough stone	5	30~35	497	Weak	Very weak
6	Natural	Light blue	Emerald	5	40~45	495	Very weak	Weak
7	Natural	Blue	Rough stone	5	25~30	497	Middle	Weak
8	Natural	Blue	Ellipse	5	40~45	492	Middle	Weak
9	Natural	Blue	Rough stone	4~5	35~40	510	Middle	Weak
10	Natural	Colorless	Ellipse	5	15~20	500	No	No
11	Natural	Colorless	Rough stone	4	25~30	505	Weak	Very weak
12	Natural	Colorless	Rough stone	4.5	15~20	491	Weak	Very weak
13	Natural	Colorless	Rough stone	4	15~20	499	Weak	Very weak
14	Treated	London blue	Marquise-shaped	6~7	10~15	492	Weak	No
15	Treated	London blue	Brilliant	7	5~10	491	Weak	No
16	Treated	Swiss blue	Ellipse	6	5~10	497	Weak	No



Sky Blue



London Blue



Swiss Blue

Figure 1. Blue topaz produced by three routine irradiation treatments



Figure 2. CL-2 Gemstone cathodoluminescence spectroscope

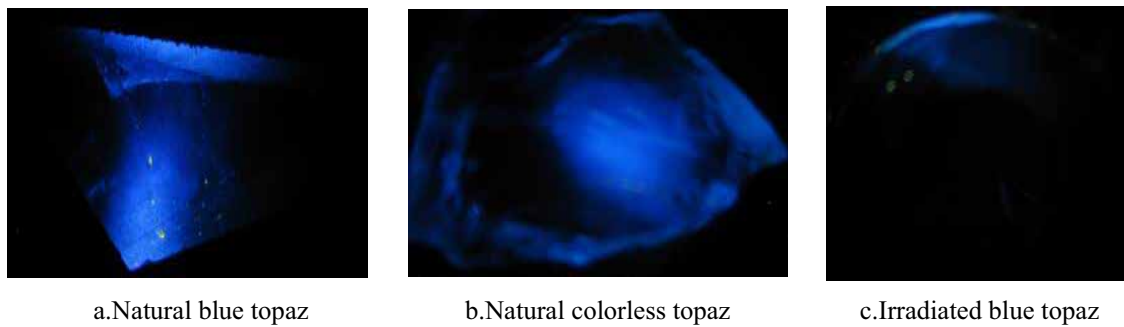


Figure 3. CL characteries of natural and irradiated blue topazs

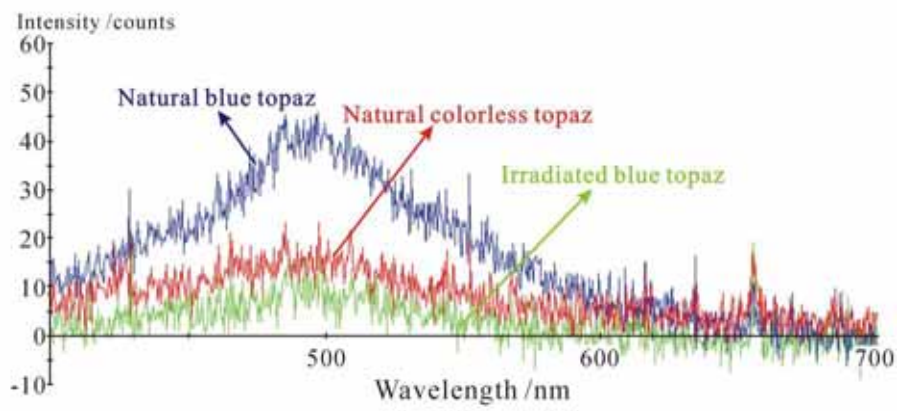


Figure 4. CL spectra characteristics of natural blue, natural colorless and irradiated topazes

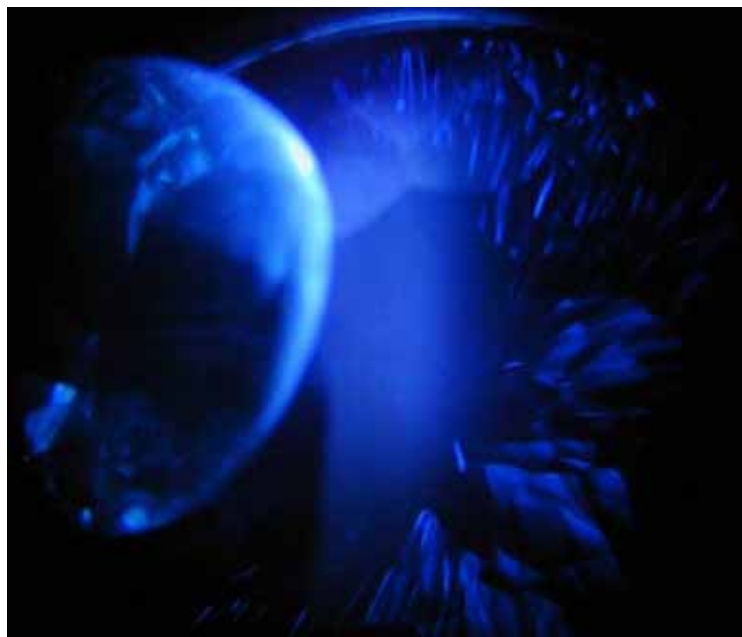


Figure 5. CL brightness comparison of natural and irradiated blue topaz



Patronage of Ecotourism Potentials as a Strategy for Sustainable Tourism Development in Cross River State, Nigeria

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Abstract

Today, Obudu Ranch Resort is one of the tourism havens in the world which has attracted great number of visitors to Nigeria and Cross River State in particular. This resort has not only aided the development of existing tourism potentials but has equally transformed the livelihood of most communities in Cross River State through income generation, employment and also provision of basic social amenities such as electricity, water supply, road network among others in the area. This paper critically examine the level of domestic and international patronage of Obudu Ranch Resort between 2001-2008, tourist preference of the resort, major attraction and facilities in the resort, population threshold of the enclave communities within the study area and the purpose of tourists visit to the Ranch Resort. Chi-square was used in testing the stated hypothesis as regards to the amount expended by the tourist as fare to the ranch. In spite of the tremendous facilities available in the Ranch Resort much is still needed to be done in order to boost the image of the Resort and also to attract high patronage of domestic and international tourists. Therefore, the hope of the masses and development of the Ranch Resort is rested on the government and the private sector.

Keywords: Ecotourism, Patronage, Tourism and Sustainable

1. Introduction

Tourism could be related to the Biblical story of the visit of the queen of Shebba to King Solomon. Tourism is seen as a leisure activity, which is international in character. Eboka (1999) described tourism as the movement of people to destinations outside their usual abode or residence on short-term bases. In the same vein, tourism is seen as a visit as well as the services industries create to satisfy the needs arising from movement within or across international boundaries temporary. In recent times, Ecotourism has attracted increasing attention in recent years not only as an alternative to mass tourism, but as a means of economic development and environmental conservation (Campbell, 2002).

Ormsby et al (2006) opened that ecotourism venture have sustained the economy of most nations for example east African countries like Kenya, Tanzania and part of West Africa like Senegal. Ecotourism is mainly the interaction between the physical environmental features for leisure purposes. It is in this light the several thousand of people live their usual residencies to areas with friendly climate, coastal regions for hiking and trekking, surfing and swimming and the enjoyment of friendly ambience. Cross River State is endowed with great ecotourism potentials such as Obudu Ranch Resort, Water Falls, Warm Spring among others which have attracted both local and international tourists patronage.

In Cross River State, the green vegetation, the rising sun, escorting many people from the capital city of Calabar, through the mangrove swamps to the tropical virgin forests to Akamkpa, Ikom and Boki, then to the mountain savannah of Ogoja and Obudu. This great eco-tourism potentials has afford several tourists and visitors a unique opportunity to see the beauty of the physical features of an enticing bride called Cross River State. Today the overwhelmed, beautiful landscapes, colourful folks, an overwhelming serenity and the agreeable climate has made Obudu Ranch Resort a natural paradise. However, this paper critically assess the level of the patronage of Obudu Ranch Resort particularly as regards to domestic and international tourist patronage of the resort between 2001-2008, tourism facilities and attraction in Ranch Resort, reason for tourists preference of the ranch, population threshold of the area and purpose for their visit to the Ranch. To achieve the above stated research findings, two hypothesis were put forward thus:

H₀: There is no significant difference between the number of tourists visiting Obudu Ranch Resort and the distance between Obudu and the tourist home.

H₁: There is significant difference between the number of tourists visiting Obudu Ranch Resort and the distance between Obudu and the tourist home.

2. Study area

Obudu Ranch Resort is located at an altitude of 1,575 meters above sea level, and a unique temperature climate and vegetation with temperature ranging between 7⁰c – 15⁰c all year round. It is a gold mine, anxiously wanting to be fully exploited. It is bounded to the north by Benue State, to the South by Ogoja local government area and the East by the Republic of Cameroon.

3. Methodology

This paper focus on patronage of ecotourism resort for sustainable tourism development in Cross River State using Obudu Ranch Resort as a case study. Data were collected in the field using Participatory Research Method (PRM), questionnaires, interview, field observation and library materials.

Three hundred and forty copies of questionnaires were administered to different tourists. While the management of the ranch resort were interview to ascertain the level of domestic and international of patronage of the ranch resort. However, participatory research method was adopted to help familiarize and also to have a focal group discussion with the different administrative cadre or staff in the ranch resort. Information concerning population threshold of the adjoining communities were collected from National population commission, Cross River State. However, the stated hypothesis was tested using chi-square to confirm the validity of the data collected in the field. The chi-square formula which is stated as:

$$\chi^2 = \frac{(f_o - f_e)^2}{f_e}$$

Nevertheless, the chi-square was used to examine the variables in the sample population.

4. Literature Review

4.1 Tourism in theory and practice

Tourism in Nigeria today is not a new phenomenon. It is also considered as one of the most profitable industries with perhaps one of the lowest possible investment. The tourist industries in Nigeria is still fairly developed when compared to those found in other countries of both the developed and developing world.

Tourism has become a powerful vehicle of economic growth which has contributed to the socio-economic development of most countries of the world especially countries like Switzerland, Brazil, Thailand among others where tourism is the main stay of her economy. (Goswami, 1979).

An instance could be cited from Spain with 2-6 million dollars from foreign tourism in 1992, this figure represents two thirds of its invisible export for that year.

(Ukpana, 2005) has contended that “domestic tourism in developing countries is a phenomenon that has so far been under estimated in scientific literature”. This statement applies to Nigeria almost more than any other country in view of the dearth of literature on this subject in the country. Among the few studies so far done on this topic with particular

reference to Nigeria is one by (Ojo, 1978) in which he traced the historical development of tourism and recreation in Nigeria from the pre-colonial through colonial to the post colonial eras of the country. He also delved deeply into the present state of the industry in the country. Ojo concluded his study with an analysis of the attitude of Nigerians to tourism and recreation using Illorin as a case study. He concluded that there is a relationship between the individual's educational background and his desire to participate in tourism. Another important variable is the individual's level of awareness of the existence of a tourist resort. It is true that a tourist will be motivated to go to any particular resort only when he is attracted and the facilities of his choice are available in such a place. Broadly speaking, the hall mark of Obudu Cattle Ranch include:

- 1) Good weather/climate
- 2) Scenery
- 3) Amenities and accommodation
- 4) Historical and cultural features
- 5) Accessibility
- 6) Natural resources such as (the hill, fertile, land, different animal species etc).

Fine weather is one of the most important attraction of a tourist center. Good weather is important in tourism that it has been capitalized upon by such places that are blessed with a unique and peculiar kind of climate. It should be stressed that in the tropics, any area with a mild or temperature climate is preferred to areas with strictly tropical climate. The development of Obudu Cattle Ranch as a holiday resort can be explained mainly by its fine and exhilarating climate which is all year round.

A report of the cognizance survey of Obudu Cattle Ranch the cultural heritage of the people describes the place as "The best site in the world to constitute a game reserve... " (UNESCO, 1979).

Beautiful and unique national scenery have also continued to be a great fascination to tourists all over the world. To be able to attract tourist in appreciable numbers, sceneries like mountains, water fall, moorland etc should combine both age and physical splendor. The importance of scenery in tourism has also emphasized by Coppock and Duffied, (1980) in observing the "scenery is the principle resource in formal outdoor recreation and that the appearance and perception and landscape are very important denominator in public enjoyment and country side. For tourists to visit any centres, there must be available facilities for lodging, swimming, recreation, amusement, games and sports, viewing etc". This then brings out the importance of the third element of tourism. Increasingly, the holiday maker has demanded entertainment and recreational facilities in larger measures. What has come to be known as "development" has preoccupied the resort management.

(Robinson, 2006) went further to say that, putting green and bathing pools, theatres, cinemas, fun palace, chair lift etc are some of the amenities is the provision of lodging and food, loosely called accommodation. The importance of accommodation lies in the fact that most tourists visit particular sport simply because there is first class accommodation where food, sleep and other things could be obtained. Features of historical and or of culture interest also exert a strong pulling force for many tourists.

However, the incomparable Egyptian pyramid, cathedrals, temple, art galleries, musical festivals, long historical and cultural significance cities like Cairo, Paris, London and other attract most tourist to these great areas.

In planning spatial behaviour (Lynch, 1975) state that "the likelihood of the person going to the particular place is a function of its attributes (resources) modified by the person's knowledge and attitude towards the attribute (perception) and further qualified by the availability of access to the place (accessibility)". By this, it implies that no matter the quality of a place, the person going there must first know that such a place exists. The physical relationship of any tourist center and the problem inadequate transport facilities which can clearly, affect the development of tourism e.g a resort can possess a much attraction and amenities that could have naturally attracted tourist, but because of accessibility, tourists will become rare bird in such a center.

Hall (2003) in his study of the impact of tourism discovered that tourism has become a significant source of foreign exchange revenue for many countries of the world. According to him, tourism activities in Maldives contributed 66.6 percent of the country's Gross Domestic Product (GDP) and accounted for 65.9 percent of its exports. According to Hall analyses, tourism industry in Vanuatu has contributed 47.0 percent of the country's GDP and 73.7 percent of its total export earnings. They went further to emphasize that thirteen (13) developed countries in Asia (Cambodia, Lao people's democratic Republic and Neps). Tourism accounted for more than 15 percent of export earnings.

There further stress that tourism alone contributed 43.5 percent of the export earnings of Fiji and one third of its GDP. Other small Islands such as Tonga and Vanuatu are dependent on tourism for half or more of their export earnings. Prentice (2007) in his study opines that tourism in China has provided a substantial contribution to its GDP, amounting

to 13.7 percent in 2006. Taking full advantage of the potential of their natural and cultural tourist resources, countries in the greater Mekong sub-region are benefiting from the tourism industry. He went further to stress that in 2006, tourism in Cambodia and the Lao people's Democratic Republic accounted respectively for 22.3 and 21.4 percent of their total export earnings and contributed 19.6 and 9.3 percent respectively of the GDP.

5. Research findings

5.1 Domestic and International Patronage of Obudu Ranch Resort

The data obtained was based on domestic and international patronage of Obudu Ranch Resort. The data collected indicate that the total number of Nigerian visitors who visit the Ranch supersede that of foreign visitors as shown in Table 1. Table 2 also reveals that there is a progressive increase of tourist patronage of the resort from 2001-2008, this could be due to improvement in infrastructural development in the Ranch Resort. The data collected also indicate that 2008 recorded the highest domestic patronage of the Ranch Resort with a value 16.843 compared to international patronage which had 6727 as present in Table 1.

Data were also collected to show the amount expended by tourist as fare to the ranch as indicated in Table 2. Table 2 reveals that the choice of the site tends to be based on the cost as indicated by the number of respondents.

To confirm the validity of the stated hypothesis using the amount expended by the tourist as fare to the ranch, the result indicates a high significance level as the computed value was 82.31 while the table value at 0.5 was 3.38. Therefore, the null hypothesis (H_0) was rejected in favour of the alternative hypothesis. Table 3 shows basic tourism attractions and facilities in Obudu Ranch Resort. These potentials are of great importance to tourists, as there is other than the best satisfaction to different categories of tourists that visit the ranch resort.

5.2 Major Tourism Attractions And Facilities In Obudu Ranch Resort

The ranch resort affords many people a unique opportunity to see the beauty of the physical features of an enticing "bride" called Cross River State. The overwhelming beautiful landscapes, colourful folks, agreeable climate and vegetation welcome visitors to the highland of the state. However, there are different facilities provided for tourists at the ranch resort. However, these facilities range from conference centre, education centre, main restaurant, cable car, traditional huts, fire station, honey moon, warehouse, new reception zone among others. Most of these facilities also provide other sub units such as library/research, shop, storage convenience, tea rooms, changing rooms for male and female among others. The provision of all these facilities by the government and private sector is in a bid to boost the image of the ranch and also to create an enabling environment for visitors wishing to patronage the resort.

Table 3 indicates reasons why tourists preferred visiting the Ranch Resort. The data collected reveals that most people are attracted to the climatic condition of the Ranch Resort as it had a value 35.6% followed by the facilities in the Resort with 24.8%. Although other factors such as scenery with a value 21.7%, popularity of the Resort 10.8% are also responsible for why people visit the Ranch. However, the data collected in table 4 reveals that almost everybody visits the Ranch due to climatic and weather condition and scenery of the environment. Other factors such as availability of facilities with 24.8%, popularity of the resort 10.8% and others were also responsible why certain persons visit the ranch.

The ranch which has a temperate weather condition is very unique and has different characteristics of this part of the world. Table 4 shows the population threshold of the various communities within the study area. The population of the various communities was obtained from development in Nigeria 2003 and the Quash Bully & Association 2008. The population indices obtained reveals a fluctuation in population of the different communities such as Anape, Okpazawge, Kogol, Keji-Ukwu, Okwamu and Apeh-Ajil respectively as shown in the table 4.

The data collected also reveals that 10.5% of the tourists are researchers, 25.2% are for Business, 8.5% visit the ranch for the purpose of attending conferences.

6. Conclusion

Tourism development in Cross River State is a phenomenon which has impacted significantly to the livelihood of most Nigerians in general and Cross River State in particular through income generation, employment and has also transformed most of the enclave (rural) communities endowed with these laudable potentials into a natural paradise through the provision of basic amenities and infrastructures such as road network, electricity, pipe borne water amongst others. Today Obudu Cattle Ranch is a distributive hub in West Africa and has attracted domestic and international tourists and visitors all over the world into Nigeria in general and Cross River State in particular hence making Cross River State a holiday town. However, the sustainability (future use) of the Ranch Resort lies in the hands of all the stakeholders such as private individual, the government and the local people whose livelihood depends solely on the environment of this great industry and potentials. Therefore, the private individual and government must advocate programmes and policies that will enhance the livelihood of these local communities within these areas so as to salvage environmental problems such as unemployment, poverty, theft among others capable of disorganizing the entire ecosystem and the ranch resort in particular.

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Table 1. Patronage of Domestic and International Tourist between 2001-2008 in Obudu Ranch Resort

Year	Number of Visitors Nigerian	% of Total	Number of Visitors Foreigner	% of Total
2001	1231	1.88	253	1.39
2002	1613	2.47	373	2.05
2003	3074	4.70	536	2.95
2004	6307	9.65	921	5.07
2005	9715	14.87	1312	7.22
2006	12,091	18.50	3117	17.16
2007	14,467	21.14	4922	27.10
2008	16,843	25.77	6727	37.04
Total	65,341		18,161	

Source: Resort Management 2008

Table 2. Amount Suspended by Tourist as Fare to the Ranch

Amount (₦)	Response Frequency	% of Sample
Below 5,000.00	106	41.9
5,000.00 – 14,000.00	63	25.82
15,000.00 – 25,000.00	36	14.75
25,000.00 – 34,000.00	28	9.24
35,000.00 and above	81	12.71
	314	

Source: Fieldwork 2008

Table 3. Tourist's Preference of Obudu Ranch Resort

S/N	Reasons for preference Obudu Ranch Resort	No of Respondent	Percentage
1	Climate/weather	112	35.6
2	Scenery	68	21.7
3	Availability of facilities	78	24.8
4	Popularity of the resort	34	10.8
5	Others	22	7.0
	TOTAL	314	

Source: Field Work 2008

Table 4. Population Threshold of Communities in Obudu Ranch Resort

S/n	Village	2003 *		2004 +	
		Population	Average Household size	Population	Average Household size
1	Anape	336	8	958	22
2	Okpazawge	225	9	693	19
3	Kegol	286	13	770	20
4	Keji-Ukwu	221	13	678	24
5	Okwamu	112	8	444	18
6	Apeh-Ajili	165	15	567	28
		1,345	11	4110	22

Source: * Development in Nigeria 2003

+ Quash Bully & Associates 2008

Table 5. Purpose of Tourist visit to the Ranch

Purpose of visit	No of respondents	Percentage
Business	79	25.2
Leisure	53	16.9
Holiday	108	34.4
Research	33	10.5
Conference	27	8.6
Any other (specify)	14	4.5
Total	314	100

Source: Field Work 2008

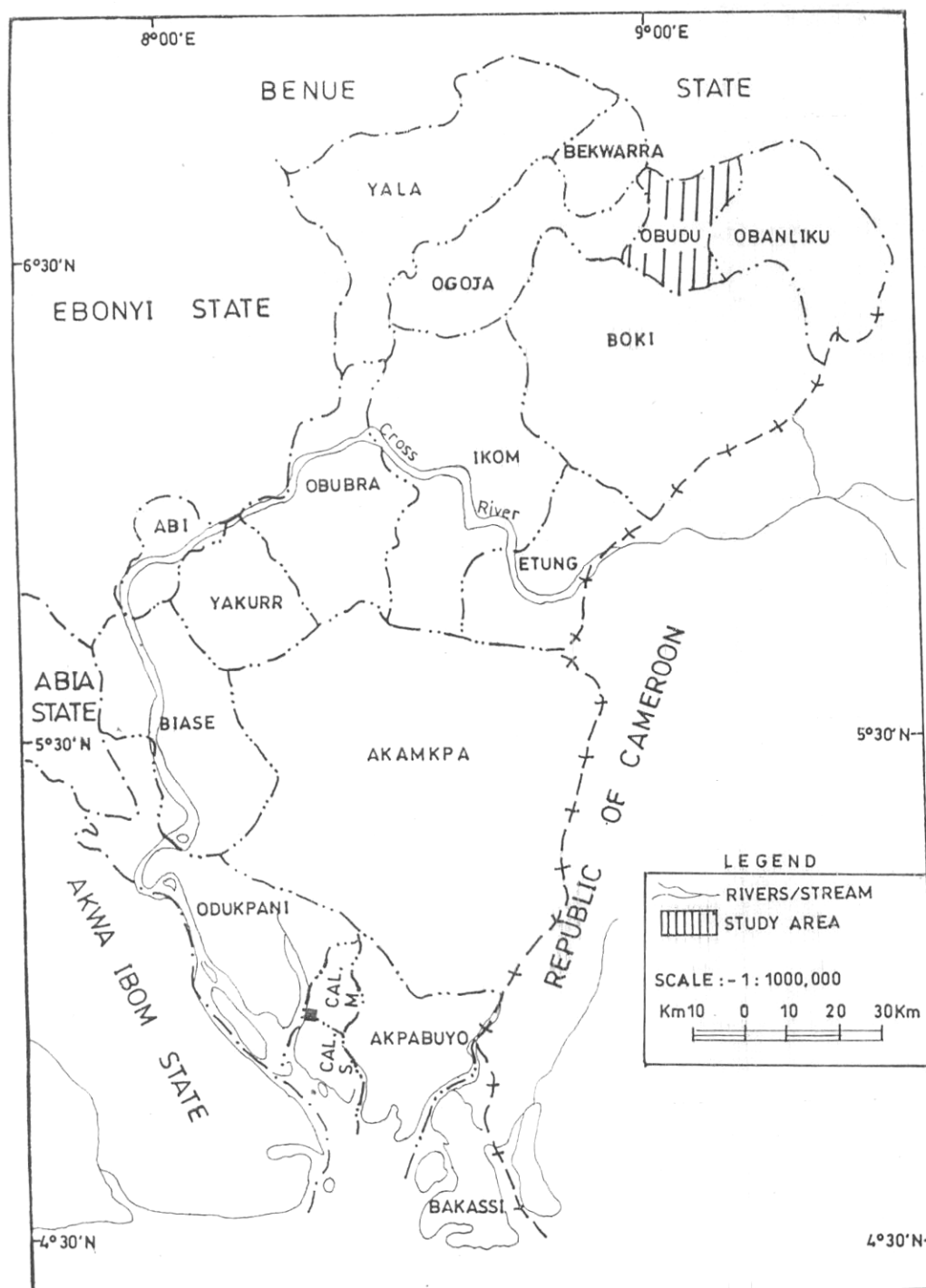


FIG. Map of Cross River State showing study area

Figure 1. Map of Cross River State showing study area



Factor Analysis-Based Optimal Selection of Rock-Breaking Bit Applied in Deep Layer of Songliao Basin

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Abstract

Correctly choosing rock-breaking bit is critical in oil drilling. The optimal model of selecting a bit has been established based on the Factor Analysis Theory. Through selecting primitive variables, and using SPSS (Statistical Package for the Social Sciences) to get factor loading matrix, factor rotation and factor score, we have reasonably evaluated and optimized the selection of rock-breaking bits applied in deep layer drilling of Songliao Basin. The calculated results are consistent with the observation from actual applications. It indicates that the method studied here is reasonably reliable and valuable for broader applications.

Keywords: Bit selection, Factor analysis, Songliao Basin, Volcanic rock

1. Introduction

The deep layers of Songliao Basin are rich in natural gas. It is imperative to extensively explore the natural gas in this region (Zhao, Wenzhi, 2004, p. 45-51). However, the geological structure of this region is complex. Complex volcanic system was broadly developed (Yang, Minghe, 2008, p. 76-87). Therefore, to achieve a safe, efficient and low-cost oil drilling process has been the major focus for scientists and engineers for a long time. One of the critical issues is correctly choosing rock-breaking bits.

Good progress has been made in the research of bit selection. Many selection modes have been proposed (Zhang, Hui, 2007, p. 1-5). Bit selection involves many variables, and is essentially an issue of multivariate statistical analysis. Many multivariate methods have been developed. Factor analysis is a widely applied multivariate statistical analysis method (He, Xiaoqun, 2004, p. 167-180; Bryan F J Manly, 1986, p. 1-15; G A F Seber, 1984, p. 21-27). In view of the actual characteristics of bit selection in oil drilling, the author has developed a factor analysis-based bit selection method.

2. Principle and model of factor analysis

Factor analysis is a multivariate statistical method which treats a system of multiple variables of intricate relationships by a few generic variables (He, Xiaoqun, 2004, p. 167-180; Bryan F. J. Manly, 1986, p. 1-15). The basic idea is to group the variables according to their correlations, i.e. group those highly correlative variables in the same group and lightly correlative variables in different groups. Each group represents a basic structure which is called "common factor", and is expressed with an unobservable generic variable.

Suppose that there are n samples and p observation indexes per sample, where the observation indexes have significant correlations. Let X represent the standardized variable vector and F represent the standardized common factor. If both X and F satisfies the following conditions:

- (1) X (observable random vector) = (X_1, X_2, \dots, X_p) , $E(X)$ (mean vector) = 0, $\text{cov}(X)$ (covariance matrix) = Σ , and Σ (covariance matrix) = R (correlation matrix).
- (2) F (unobservable variable) = (F_1, F_2, \dots, F_m) , ($m < p$), and the components of vector F are mutually independent.
- (3) $\varepsilon = (\varepsilon_1, \varepsilon_2, \dots, \varepsilon_p)$, is independent from F , and the components of ε are mutually independent.

" $X = AF + \varepsilon$ " is a basic model of factor analysis (He, Xiaoqun, 2004, p. 167-180).

3. Procedure of factor analysis-based bit selection

3.1 Selection of primitive variables and their standardized processing

Select variables that represent different types of bits at different geological layers, such as bit pressure, drilling time, drilling footage and unit price of bit. The established matrix (X') of primitive variables is as following expression.

$$\begin{cases} X'_1 = a_{11}F_1 + a_{12}F_2 + \cdots + a_{1m}F_m + \varepsilon_1 \\ X'_2 = a_{21}F_1 + a_{22}F_2 + \cdots + a_{2m}F_m + \varepsilon_2 \\ \dots\dots\dots \\ X'_p = a_{p1}F_1 + a_{p2}F_2 + \cdots + a_{pm}F_m + \varepsilon_p \end{cases} \quad (1)$$

Here, F_i represents the i^{th} common factor, and a_{ij} represents factor loading.

In order to avoid the influence of different dimension and magnitude to the final statistical results, the primitive variables need to be standardized as the following (2).

$$X_i = \frac{X'_i - \overline{X'_i}}{\sqrt{\text{var}(X'_i)}} \quad (2)$$

3.2 Determination of factor loading matrix

There are many methods for the determination of factor loading matrix, such as main-component analysis, principal axis factor method, least square method and maximum likelihood method (He, Xiaoqun, 2004, p. 167-180). The principal axis factor method is used in this paper.

From formula (2), we can determine the matrix X -related correlation matrix R as following formula (3).

$$R = AA' + \Sigma\varepsilon \quad (3)$$

Here, A represents factor loading matrix, and $\Sigma\varepsilon$ represents a pair of diagonal matrix with its diagonal elements being the variance of special factors thereof.

Assume that $\lambda_1^* \geq \lambda_2^* \geq \cdots \geq \lambda_m^*$ are the characteristic roots of correlation matrix R , and $\gamma_1^*, \gamma_2^*, \dots, \gamma_m^*$ are corresponding orthonormalized eigenvectors. Therefore, an axis factor of factor loading matrix A is determined by the following formula (4).

$$\tilde{A} = (\sqrt{\lambda_1^*}\gamma_1^*, \sqrt{\lambda_2^*}\gamma_2^*, \dots, \sqrt{\lambda_m^*}\gamma_m^*) \quad (4)$$

3.3 Factor rotation

Factor rotation is determined based on the varimax rotation method in this paper.

First, we take the plane of two common factors into account. Assume that the factor loading matrix is represented by the following expression (5).

$$A = \begin{Bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \\ \dots\dots\dots \\ a_{p1} & a_{p2} \end{Bmatrix} \quad (5)$$

Let T be an orthogonal matrix by the following expression (6).

$$T = \begin{Bmatrix} \cos \phi & -\sin \phi \\ \sin \phi & \cos \phi \end{Bmatrix} \quad (6)$$

Let $B = (b_{ij}) = AT$, then the following expression (7) is obtained.

$$B = \begin{Bmatrix} a_{11} \cos \phi + a_{12} \sin \phi & -a_{11} \sin \phi + a_{12} \cos \phi \\ a_{21} \cos \phi + a_{22} \sin \phi & -a_{21} \sin \phi + a_{22} \cos \phi \\ \dots\dots\dots \\ a_{p1} \cos \phi + a_{p2} \sin \phi & -a_{p1} \sin \phi + a_{p2} \cos \phi \end{Bmatrix} \quad (7)$$

The squared values of two lines of elements in the rotated loading matrix are standardized to 0 and 1. Therefore, The sample variances V_1 and V_2 of the above-mentioned squared values ($b_{11}^2, b_{21}^2, \dots, b_{p1}^2$) and ($b_{12}^2, b_{22}^2, \dots, b_{p2}^2$) should be maximized. For this reason, the orthogonal rotation angle (Φ) is required to satisfy the equation of “ $V_1 + V_2 = \max$ ”, that is

$$V = \sum_{j=1}^2 \left[\frac{1}{p} \sum_{i=1}^p (b_{ij}^2)^2 - \left(\frac{1}{p} \sum_{i=1}^p b_{ij}^2 \right)^2 \right] = \max \quad (8)$$

As a general rule, take two factors every time and turn all of them into rotating pairs when the number of common factors is more than two.

3.4 Calculation of factor score and comprehensive analysis

The regression equation (9) is established with the common factor as the dependent variable and the primitive variable as the independent variable.

$$F_j = \beta_{j1}X_1 + \beta_{j2}X_2 + \dots + \beta_{jp}X_p \quad (9)$$

Based on the least-square regression approach, the estimated value of F is determined by the equation “ $F = A'R^{-1}X$ ”. Here, A' represents the transpose of the rotated factor loading matrix; R^{-1} represents the inverse matrix of the primitive variable-related matrix; and X represents the primitive variable vector.

The applications of different types of bits at different layers are evaluated on the basis of the weighted sum of all factor scores for each bit. The bits are in turn optimally selected based on the obtained data.

4. Examples of calculation

4.1 Geologic characteristics of deep layers in the north part of Songliao Basin

Songliao Basin, in the northeast part of China, is a large-scale oil-contained meso-cenozoic continental basin. The basin basement consists of the middle-kata metamorphic rock series of Proterozoic and early Paleozoic eras, and low metamorphic rock series of late Paleozoic eras and volcanic rock. From bottom to top, it consists of the upper Jurassic Huoshiling formation, lower Cretaceous Shahezi formation, Yingcheng formation, Dengloulou formation, Quantou formation, upper Cretaceous formation, Yaojia formation, Sifangtai formation, Mingshui formation and Cenozoic formation. The formation from Shahezi to Yingcheng is the deep major hydrocarbon source rocks, and Dengloulou formation is the minor hydrocarbon source rocks.

4.2 Examples for bit optimal selection

Different types of bits applied in the deep Dengloulou formation at Xujiaweizi region of Songliao Basin are statistically analyzed. The applications of bits in the well X3 at this region are shown in table 1.

The bits applied in the Dengloulou formation are optimally selected based on the method studied in this paper. The factor analysis can be achieved by the “Factor Analysis module” in SPSS. The SPSS-analyzed factor scores of various bits are shown in table 2.

The various bits are optimally selected on the basis of the weighted sum of all factor scores for each bit. The results are shown in table 3.

The results in table 3 are basically consistent with the observation from actual applications. It indicates that the method is practicable.

5. Conclusion

(1) Factor analysis is an important multivariate statistical analysis method, and has a bright future for applications in practical engineering tasks.

(2) The above-mentioned SPSS is powerful, convenient and easy to use.

(3) The factor analysis-based optimal selection results of bits basically reflect the actual on-site use. It indicates that the method is relatively reliable and valuable for broader applications.

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Table 1. The applications of bits in the well X3 at Dengloulou formation

Serial number	Type of bit	Drilling footage (m)	Drilling time (h:min)	Drilling speed (m/h)	Drilling pressure (kN)	Rotation speed (r/min)	Displacement (L/s)	Pumping Pressure (MPa)
1	HJS537GR	129.16	105:55	1.22	260	132	46	22.0
2	HJS537GR	151.60	119:15	1.27	260	132	46	22.0
3	HJS537GR	116.66	129:10	0.90	280	65	45	20.0
4	HJS537GR	149.31	121:05	1.23	280	65	45	20.0
5	HJT547G	40.69	32:10	1.26	200	50	30	19.0
6	HJT617GL	115.12	79:15	1.45	180	50	30	17.0
7	HJT617GL	74.41	52:05	1.43	180	50	30	18.0
8	TD53HR	130.43	56:20	2.32	180	78	32	18.0
9	TD53KPRDH	85.87	64:25	1.33	180	78	32	18.0
10	HJS537GR	187.42	105:25	1.78	180	78	32	17.0
11	HJ517G	163.59	81:15	2.01	180	70	33	17.7
12	HJ517G	158.05	103:25	1.53	180	70	34	17.0

Table 2. The SPSS-analyzed factor scores of various bits applied in Dengloulou formation

Serial number	Type of bit	Main factor 1	Main factor 2	Main factor 3
1	ATJ33	0.572	-0.652	0.368
2	ATJ44	1.685	0.365	0.369
3	ATM33	-0.438	0.655	-0.358
4	DQ506	0.537	0.325	2.355
5	FG45YODPD	0.580	0.365	0.258
6	H617	2.367	0.562	0.354
7	HA617L	0.235	0.255	0.355
8	HA617LC	0.234	-0.352	-0.158
9	HA637LC	0.531	1.365	-0.269
10	HJ517G	0.756	2.365	0.452
11	HJ617	-0.747	-0.258	-0.254
12	HJ637	0.721	0.354	0.324
13	HJS537GR	1.256	0.324	2.325
14	HJT547G	0.835	1.185	0.254
15	HJT617GL	0.243	1.365	-0.365
16	HJT737GDG	-0.543	0.368	-0.487
17	SC-279	-0.124	-0.369	-0.452
18	TD53HR	0.281	0.254	-0.154
19	TD53KPRDH	-0.251	0.324	0.104

Table 3. The optimal selection results of bits

Formation segment	Selection results
Dengloulou 4 th	HJT547G, HJS537GR, HJ517G
Dengloulou 3 rd	HJS537GR, HJ517G, HJT617GL, HJT547G
Dengloulou 2 nd	HJS537GR, HJT617GL, HJ517G



Assessment of Wetlands in Kuala Terengganu District Using LandsatTM

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Abstract

Wetland cover mapping is very important in identifying its areal extent and the rate of change over time. This study aims to map the areal extent and its rate of change in Kuala Terengganu district which covers approximately 4,690.65 hectares. Three LandsatTM images, which dated on 15th October 1998, 14th July 2002 and 15th August 2005 were used in digital image processing by using a RGB band combination of 4, 5, and 2. The overall classification accuracies for the 1998, 2002 and 2005 images were 74.55, 82.42 and 90.91 percent, respectively. The United State Geology Survey (USGS) Classification Scheme was used to determine the wetland and the images were independently classified and total areas of wetland cover were compared between different dates of imageries. Surprisingly, there was an unexpected significant increase (from 102.35 to 381.35 ha) in the areal extent of wetlands in a seven year period of 1998 to 2005 with a rate of change of 0.84% increase per year. This study implies that the integration of remote sensing and Geographical Information System (GIS) may provide a useful tool for temporal studies in wetland cover and its rate of change in Kuala Terengganu district.

Keywords: Wetland, Remote sensing, Rate of change, Setiu

1. Introduction

Biodiversity can be defined as full range of variety and variability within and among living organisms and the ecological complexes in which they occur, and encompass ecosystem, species diversity, and genetic diversity. It is predicted that our country has a high biodiversity, as Malaysia lies in the tropics, where the climate is very suitable for a high number of species in the world that mostly inhabitants in the ecosystems of our country. Furthermore, Malaysia is also listed as one of the biodiversity hotspots in the world. Malaysia has been endowed with vast amount of natural resources including luxuriant wetland forest, which is one of the most diverse and complex ecosystems of the world. These natural resources have been identified to provide habitats for many species and providing important regional impacts, such as hydrological, biological and ecological roles in the ecosystem. Therefore, it is our responsibility to manage the wetlands well, as well as conserving them for the future.

Malaysia has a total of 96 wetlands sites approximately covered 0.34 million ha of peat swamp which was reduced almost half from 0.67 million ha in 1981 (Abdur-Rouf *et al.*, 2007). Malaysia needs to conserve these important ecosystems for addressing flood problems, mitigating el-nino effects, estimating national water budgets and conserving biodiversity. In example, Table 1 showed the richness and diversity Malaysia aquatic ecosystem.

<<Table 1: Aquatic ecosystems in Malaysia>>

Mapping wetland vegetation over larger regions has commonly been done using digital imagery obtained from satellites, and may be referred to as land cover mapping. Wetland cover mapping is actually providing critical information about the distributions of the species and vegetation types and “human land uses” surrounding it, thus, possible for biodiversity conservation planning, as the wetland cover classifications may link to a particular species composition and

habitat types. In this case, wetland cover maps produced may provide the baseline measurements that allow the study of changes in a particular land cover over time and further discover the impacts of such changes on the biodiversity. Maps arranged according to their dates may reveal the patterns (Mitchell, 1999) and help the interpreters to infer the relationship (Turner *et al.*, 1994) between the maps studied. Meanwhile, statistics in table forms summarize the findings to specifically display the increment and reduction of total areas that changed over time.

In addition, most maps used by the ecologists are land cover maps (Burel and Baudry, 2003), created from the analysis of the satellite imageries, together with aerial photographs, and through field observations that has been done by the scientists from remote sensing fields. Often, landscape ecologists use the final products of GIS processing or the interpretation of spectral data to conduct their study, as many of them are not technically proficient in all the intricacies on spatial extents that are much larger than those traditionally studied in ecology (Turner *et al.*, 2001). Therefore, the objectives of this study are two-folds, namely (i) to map the wetland cover of Kuala Terengganu district and to determine its rate of change between 1998 and 2005, and (ii) to produce final wetland cover maps of Kuala Terengganu for each year of study

2. Method

The selected area of study was Kuala Terengganu district of Terengganu state, as shown in Fig.1. Kuala Terengganu is located between latitudes of 5° 27' 58.31" N and 5° 11' 42.36" N and longitude of 102° 57' 06.10" E and 103° 13' 18.69" E. The capital city of Terengganu state is located in this district. The total study area is approximately 60,528 ha, which covers 4.67 percent of the Terengganu district. Three sheets of 1:50,000 scaled topography maps were used as a reference to conduct the ground truthing process. Two softwares were used in this study. Erdas Imagine 8.7 was used in the digital image processing, while ArcView 3.2 was used for the GIS analysis.

Landsat TM was acquired from scene 126/56 (path/row), with spatial resolution of 30 m. Images were obtained from Malaysian Center for Remote Sensing (MACRES). These images were taken on 15th October 1998, 14th July 2002 and 15th August 2005. The raw images of the study areas were shown in Fig.2 by using the band combination of RGB 4, 5, 2.

<<Fig. 1 Location of the study area>>

<<Fig. 2 Raw image of Kuala Terengganu August 15, 2005>>

Multi-dates images of Kuala Terengganu district were used to initiate this task, which involved images of 1998, 2002 and 2005. A uniform interval was expected in order to determine the land cover changes rate, but unfortunately, a uniform three or four year's intervals are not available in the archive. The seven bands of each image were layer stacked to merge them together, before producing a single image. Geometric correction process was done based on the Ground Control Points (GCP) taken during the ground truthing. A total of 50 GCPs were registered for each image; they were resampled to produce the corrected imaged. All corrected images were justified based on Root Mean Square Error (RMS Error) of less than half a pixel (Lillesand *et al.*, 2004) by using the First Polynomial Order. The images used Rectified Skew Orthomorphic (RSO) Projection with Spheroid of Modified Everest and Kertau 1948 as the Datum. In unsupervised classification process, Iterative Self Organizing Data Analysis Technique (ISODATA) was applied to the 100 classes of unknown land covers with 30 iterations. This process is then followed by redefining the criteria for each class and classifying them again before producing the last output images of the unsupervised classification process. Wetland class was identified roughly based on the analyst's prior knowledge and from analyzing the topographical maps.

During the ground truthings, the actual wetland cover class involved was checked and identified. Global Positioning System (GPS) Garmin GPS 12 with accuracy 15m RMS was used to acquire the exact coordinates of study areas (GCP), while photographs of the wetland cover class was captured together with their details recorded. The images were then classified into wetland cover types. The analysis was done using data collected during the ground truthings with the aid of topographic maps to produce the output images of supervised classification. Next, they were filtered through the Statistical Filtering by using 7x7 modes. Mean Filter was applied for all these output images before recoding them according to the wetland class, in order to measure the areal extent of the wetland rate of change per the years studied. The output images for supervised classification process were assessed to determine the classification accuracy. Stratified Random Sampling was applied to each supervised classification images, where 30 random reference pixels were taken into account. The accuracy report was generated later that comprised the summary statistics of overall agreement percentage, together with user's and producer's accuracy. All the output images from the supervised classification were used in the GIS Analysis to determine the changes occurred amongst the temporal years under study. Each image was independently classified and registered before undergone the post-classification comparison. The rate of change was determined after calculating the total areas of wetland cover class. The changes in distribution of wetlands were shown in the generated wetland cover maps.

3. Results and discussions

Unsupervised classification was done to assist the ground truthing. Besides the wetland there were eleven other classes of land cover with uncertainties of the actual locations predicted during this process. The eleven classes are barren land, cloud, cloud shadow, forest land, oil palm, orchard, paddy, rubber, urban or built-up land, and water. They were nine classes categorized including the wetlands which were confirmed using ground verifications. Land cover classes for supervised classification images include the cloud and cloud shadow, which appeared in the images. Fig. 3 shows the images that have undergone the supervised classification that was further subset to highlight only the study area, which is the Kuala Terengganu district. A summary of the total area for each land cover classes, especially the wetlands in every image were demonstrated in Table 2 according to their respective year of study to measure the rate of change for the three temporal years.

<< Fig. 3 Supervised classification image of K. Terengganu for 1998, 2002 and 2005>>

<< Table 2. Total areas of land cover and land use for 1998, 2002 and 2005 image of K. Terengganu>>

Based on the results, all Root Mean Square Error (RMS Error) obtained are less than a pixel. In this study, the spatial resolution of each data used is 30 m, which represented by a pixel. Therefore, the errors obtained should not be more than the image resolution, which means not more than 30 m. Furthermore, for the change detection analysis, a requirement of accurate spatial registration during geometric correction could bring an effective result for each dates of imagery. Ideally, the RMS Error should not be more than half a pixel.

3.1 Accuracy assessment

In accuracy assessment, a total of 330 stratified random sampling points was used to determine the accuracy for each output images of the supervised classification. The overall classification accuracy obtained for 2005 image is the best, which is 90.91%. The overall accuracy for 1998 and 2002 images can be considered as moderate, where the accuracies are 74.55 % and 82.42 %, respectively.

3.2 Geographical Information System (GIS) analysis

Arc View 3.2 software was used in the GIS analysis to enable determination of the total changes of areas for each class, when the images were compared. The arrangement of the classes was done by putting the priority, based on the highest to lowest increment of total area that changed from 1998 to 2005, and further followed by the highest to lowest changes reduction of the total area. For wetland class, distribution of the particular land cover is shown in Figure 4. In 1998, the total area is 2.18 % or 102.348 ha. The value decreased slightly in 2002 to be 2.15 % or 100.683 ha. Surprisingly, the value of total area of this class expanded in 2005 to be 8.13 % or 381.348 ha.

<<Fig. 4 Wetland covers type maps of K. Terengganu for 1998, 2002 and 2005>>

The total area of wetlands has increased to 5.95 % or 279 ha from 1998 to 2005. In 2005, the total area for wetlands was observed to be higher compared to the earlier years of study. This might be due to the inexperienced analyst, where the spectral reflectance of other land use cover such as rice paddy areas was misinterpreted as wetlands. Meanwhile, in 2005, the areas of Wetland class were observed in more detailed, as the ground truthings enable determination of the exact wetland cover involved in the area. Furthermore, seasonal peat swamps are included in this class, where this class is influenced by the water table to be mistakenly interpreted as the rice paddies class. Basically, the weakness in interpretation of this class is due to the lack of knowledge of the study area in the earlier years of study.

With the aid of ground truthing and further analysis of the ancillary data, it is observed that the wetlands of K. Terengganu district were found in Kampung Mengabang Panjang in Batu Rakit, Kuala Nerus subdistrict, Gong Badak industrial areas and Gelugur Raja, mainly associated with wetland floras of sea hibiscus (*Hibiscus tiliaceus*), nipah palm (*Nypa fruticans*) and mangrove fern (*Acrostichum aureum*). Forested wetland is dominant in Kuala Terengganu and most of the mangrove trees observed were *Avicennia*, *Sonneratia*, *Rhizophora* and *Melaleuca* genera.

Wetland areas have their own international importance, as they provide the natural protection to the coastal areas from the strong storms, as well as the sand erosion. They have a high biological diversity and traditionally utilized for food resources, firewood, charcoal and timber (Yousif *et al.*, 1999). Wetland has been recognized to be the breeding areas and refuges for many marine species, including prawns. Mangrove is also capable in preserving water quality and reducing the water pollutions by filtering suspended materials and assimilating dissolved nutrients. Since wetland areas protect the human and the human settlements, they are eventually have become our responsibility to take care of them, so that people do not have to worry too much about the disasters that might occur if these areas are eliminated.

4. Conclusion

LandsatTM images are capable of identifying the wetland cover class and its rate of change. Overall classification accuracy obtained for 1998, 2002 and 2005 images are 74.55 %, 82.42 % and 90.91 %, according to their respective years of study. These values show a moderate accuracy for 1998 and 2002 images, meanwhile, 2005 image has the best

accuracy assessment. Wetlands sometimes confuse with rice paddies class. Generally, the integration between remote sensing and GIS in this study has proved its ability to determine the wetland cover classes, as well as the other land cover changes between the study periods. It is recommended that the satellite imageries with higher spectral and spatial resolutions be used for future wetland cover map production in order to improve the mapping accuracy.

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Table 1. Aquatic ecosystems in Malaysia

Habitat	Area (km ²)
Peninsular Malaysia	
Rivers including floods plains	9,111
Peat swamps	4,850
Reservoirs	1,600
Mining pools	164
East Malaysia	
Rivers including flood plains	8,487
Peat swamps	15,150
Reservoirs	22
Total	39,384

Source: Yusoff and Gopinath, 1995

Table 2. Total areas of land cover and land use for 1998, 2002 and 2005 image of K. Terengganu

Classes	1998		2002		2005	
	Ha	%	ha	%	ha	%
Barren Land	92.22	1.97	39.46	0.84	63.135	1.35
Cloud	204.96	4.37	140.87	3.00	66.321	1.41
Cloud Shadow	185.86	3.96	76.04	1.62	9.639	0.21
Forest Land	264.40	5.64	77.39	1.65	49.437	1.05
Oil Palm	58.46	1.25	238.19	5.08	382.329	8.15
Orchard	1612.14	34.39	1841.40	39.26	1274.049	27.16
Paddy	405.06	8.64	362.27	7.72	772.182	16.46
Rubber	534.94	11.41	478.84	10.21	1017.756	21.70
Urban or Built-up Land	1109.52	23.67	1214.33	25.89	500.328	10.67
Water	118.19	2.52	121.14	2.58	174.132	3.71
Wetlands	102.34	2.18	100.68	2.15	381.348	8.13
Total	4688.13	100	4690.65	100	4690.65	100

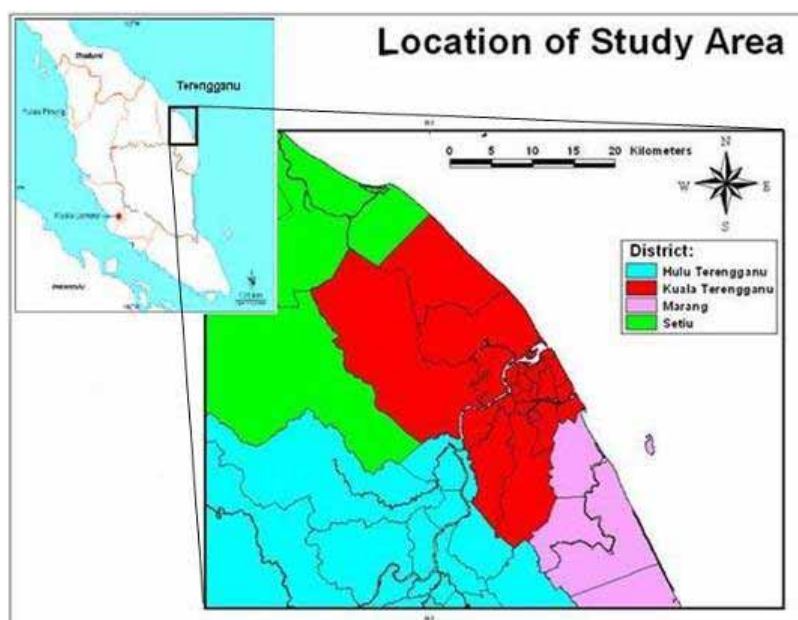


Figure 1. Location of the study area

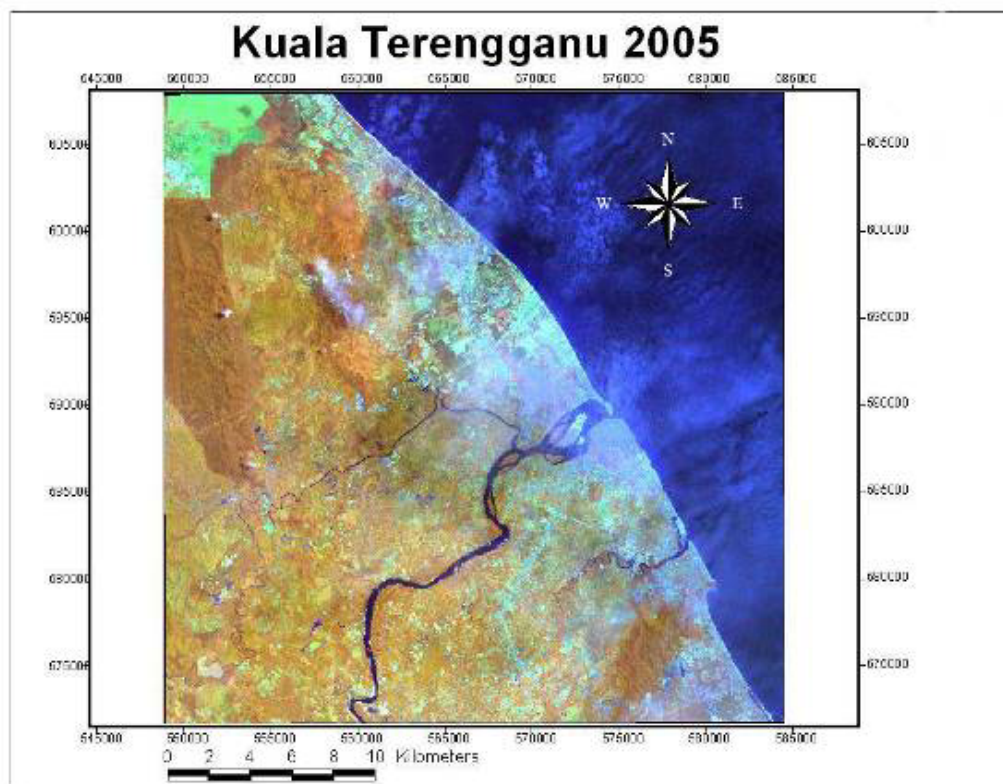


Figure 2. Raw image of Kuala Terengganu August 15, 2005

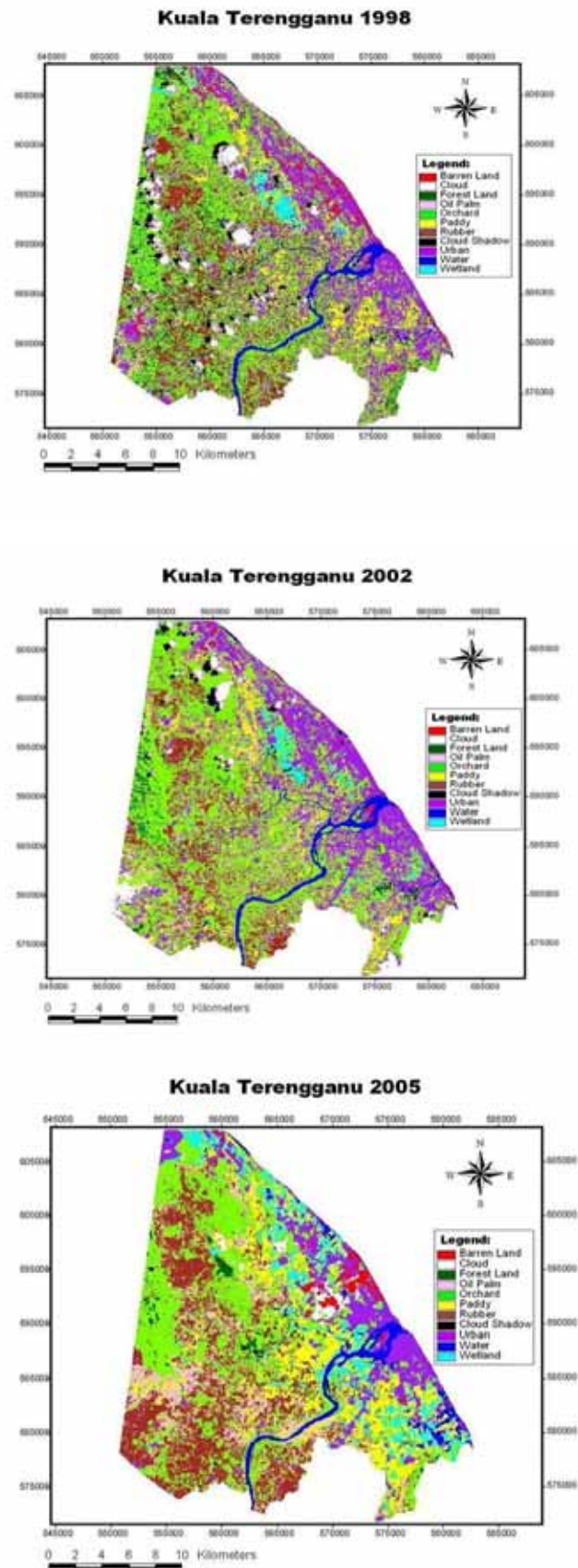


Figure 3. Supervised classification image of K. Terengganu for 1998, 2002 and 2005

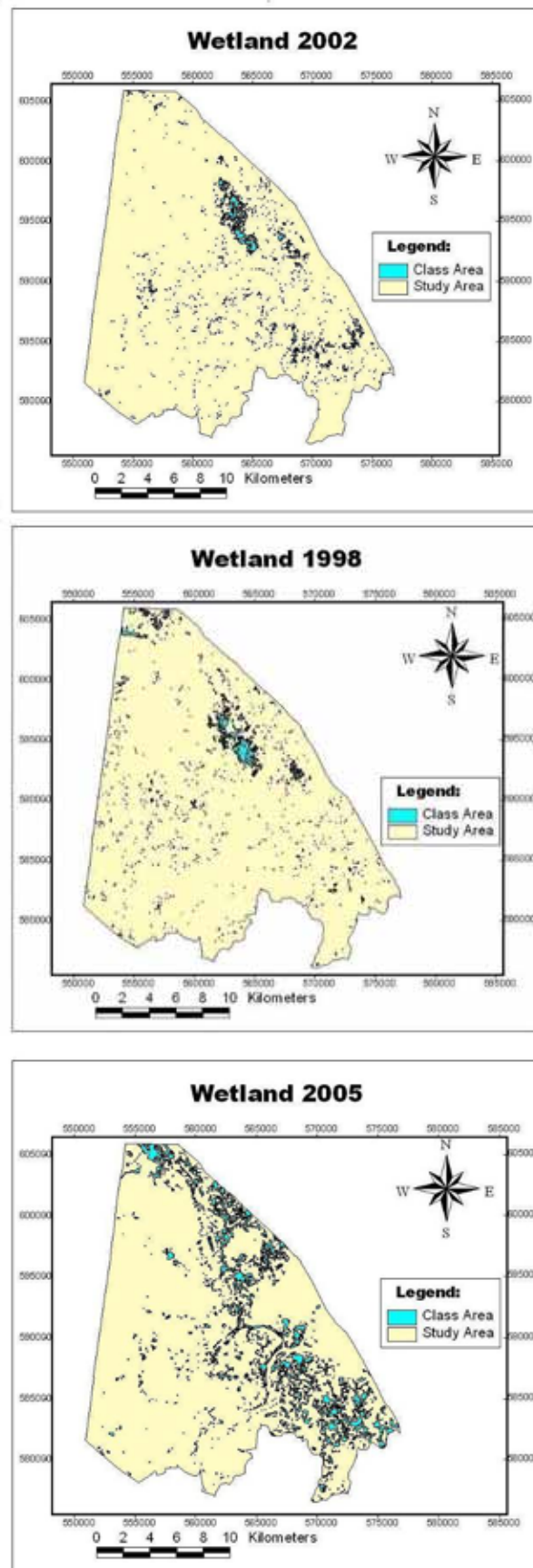


Figure 4. Wetland cover type maps of K. Terengganu for 1998, 2002 and 2005



Loess Tourism Resource Exploitation Strategy in the Chinese Loess Plateau: A Case Study of White Deer Plateau

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Abstract

As one of the important geologic tourism resources in the world, the Chinese loess landscape tourism has not been developed deeply enough, which can not fulfill tourists' tourism demands on different levels. Based on many successful development experiences about sand tourism and ice snow tourism, according to the feature of loess environment, geographic conditions and traffic advantage, combining the advantages, features and development actuality of the loess landscape on the Chinese Loess Plateau, the idea of constructing the loess sculpture garden on the White Deer Plateau is proposed in the article. The main problems existing in the tourism development of the White Deer Plateau are analyzed, and the necessity and feasibility to construct the loess sculpture garden are demonstrated, and the main contents to establish the loess sculpture garden in the White Deer Plateau are proposed. The loess sculpture garden can completely show the special natural landscapes and the humanistic landscapes in the Loess Plateau, enhance the landscape value of the loess landscapes, deeply dig the scientific and educational values, closely combining the landscape feature with the popular science oriented feature, drive the development of the tourism of the White Deer Plateau and make it to become the hot landscape and the popular science base of the tourism.

Keywords: Chinese Loess Plateau, White Deer Plateau, Tourism exploitation, Loess sculpture garden, Leisure and knowledge, Popular science bases

1. Introduction

As the important landscape in the nature, the loess geomorphic landscape in Chinese Loess Plateau has been concerned widely by the geosciences circles (Guo, 2008, P.107-124 & Xu, 2004, P.1871-1882 & B. Fu, 1994, P.33-40), but as a kind of tourism resource, the loess landscape is ignored up to now (Wu, 2005, P.513-519 & Zhao, 2007, P.95-99). The loess geomorphic landscape includes not only the loess stratum section which is the best Quaternary continental record in the world, but the erosion landscape that the soils are eroded most seriously in the world, and specific loess wonders such as loess tableland ('Yuan' in chinese), loess ridge (Liang), loess hills (Mao) (Liu T S, 1985, P.1-251), rivers and

gorges, which largely attract domestic and foreign tourists. The White Deer Plateau (here Plateau is named as Yuan in local Chinese, a tableland landform) is the largest plateau near Xi'an city, and its exposed loess stratum completely and systematically records the past environment change (Bloemendal J, 2008, P.152-168 & Zhao J, 2008, P.665-676), which possesses higher scientific and research values, and is the important resource to study the geology and develop the popular science tourism. Because the tourism development emphases of the White Deer Plateau are only limited in the Hundreds Hectares Cheery Garden and the Cetacean Channel at present, so the development of the special and abundant loess tourism resources is still ignored, which not only wastes the resources, but limits the tourism development space of the White Deer Plateau. Therefore, it is very important to strengthen the development of the loess tourism resources in the White Deer Plateau.

According to the feature of loess environment, geographic conditions and traffic advantage, combining the advantages, features and development actuality of the loess landscape on the Loess Plateau, combining with tourists' intensive requirements for the participation, knowledge and culture of the tourism products, the idea of constructing the loess sculpture garden on the White Deer Plateau is proposed in the article. The visual, lively and abundant loess physiognomy landscape, the loess and environment, and the loess culture full of Chinese characters will be utilized to drive the development of the tourism industry in the White Deer Plateau, promote the advance of the loess culture and create the new mode of geological popular science tourism. And the White Deer Plateau will be constructed as the Chinese loess geological popular science tourism base and the "large tourism plateau" in the area of Xi'an.

2. Geographic situation of the White Deer Plateau

The White Deer Plateau is located to the southeast of Xi'an City, the southwest of Lishan Mountain, and the northwest of Shaoling Plateau. It lies between the Chanhe River and the Bahe River, and its length is about 28km, and its width is about 7~10km with a area 238km², and it is the largest loess plateau near Xi'an City. The Cetacean Channel transverses the plateau, and the northern part is called as Dizhai Plateau, and the souther is called as Paoli Plateau. The altitude of the plateau ranges from 650 m to 780 m a.s.l with the highest 803.9m. The surface of the plateau rises northeast, and descends southwest, and the height differences between the northern plateau and the Bahe River are in 260~350m, and the height differences between the southern plateau and the Chanhe River are in 150~200m. The gullies and streams in the White Deer Plateau mainly include Gaojiagou gully, Shenyusi gully, Wanggou gully and Cetacean stream. The lengths of former three gullies are about 5km, but the length of the Cetacean stream is about 25km.

The tourism resources of the White Deer Plateau are abundant and diversiform, and they include the loess plateau and ravine physiognomy landscape, the graceful water landscapes such as reservoirs, springs and gullies, the woodlands and agricultural landscapes, the literature tourism resource of "White Deer Plain", the deep historical and cultural tourism resource, the famous Hanwen Baling Mausoleum, Quen Mother Bo Mausoleum, Queen Dou Mausoleum, site of Diqing Camp, the live custom culture resource, and the cave-house sites where villagers lived in early years such as Changchungou gully and Sunjiagou gully. But at present, only the Hundreds Hectares Cheery Garden and the Cetacean Channel are developed, and most tourism resources are still in the state of un-development or the state of waiting development, so the development potential of the tourism is very large.

3. Problems existing in the tourism development in the White Deer Plateau

3.1 The tourism development lacks in characters and the issues are not obvious

At present, the tourist activities in the White Deer Plateau mainly include the cherry sightseeing and picking tour and the cetacean channel reservoir sightseeing tour. Though the former is popular in recent years and it is the special tourism item which is different with the strawberry sightseeing and picking tour, the grape sightseeing and picking tour, and the guava sightseeing and picking tour around Xi'an, but its character of season is obvious and the duration is too short, and it can not present the topic tourism issues in the White Deer Plateau. The latter is largely identical but with minor differences with the valley and water landscape tour in the north of Qinling Mountain, and it can not compare with the market attraction and admittance of the valley and water landscape tour resource in the north of Qinling Mountain. The tourism development of the White Deer Plateau has not formed its own characters and attractions, so without obvious topic issues, there is not the development space of the tourism market.

3.2 The tourism product is single and the market scale is small

The tourism development of the White Deer Plateau still emphasizes traditional tourism resources such as valley, water and agriculture, and the market supply only includes sightseeing tourism products on the lower layer which are mainly to fulfill citizen's tourism demands in Xi'an, but ignore the developments of the resources such as the loess landscape, the folk-custom of the White Deer Plateau which are more interesting for middle and long-distance tourists, so the structure of the tourism product is single, and it can not fulfill the market demand of the tourists on the high layer.

4. The necessity to construct the loess sculpture garden on the White Deer Plateau

4.1 The scientific knowledge of loess can be comprehensively and systematically popularized

The popular science tourism is the necessity of the deep development in future tourism zones, and the demand to

implement the national quality education. The loess landscape in the White Deer Plateau is the important carrier to develop the science education tourism which can attract foreign and domestic experts and geology fans to review and explore, and the loess sculpture garden established in the White Deer Plateau can comprehensively present the physiognomy landscape in the Loess Plateau, the loess and ice age, the paleosol and interglacial stage, vegetation, sand storm, ground water, the loess cultural landscapes to attract common tourists who can really see the Loess Plateau and systematically know the loess science knowledge. In addition, the national quality will be enhanced in deed.

4.2 The loess landscapes on the Loess Plateau can be showed newly and visually

It is not rare to construct the tourism landscapes by the sculptures, for example, the ice sculpture (Dewar K, 2001, P.523-532) and the sand sculpture have been mature and typical mode to develop and utilize the ice resource and the sand landscape in many tourism areas, but it is new development mode to sculpture typical loess natural and humanistic landscapes of the Loess Plateau by the loess. For this mode, the topic is brighter, the connotation is more abundant, and the expression is more special, and it can enhance the tourism value of the loess landscape and attract more people's concerns. On the other hand, to really know the loess landscapes, it is not enough to only appreciate it on the spot, especially for those large-scale physiognomy landscapes such as loess tableland, loess ridge, loess hills, channel, and the physiognomy of Yellow River, tourists only see the locals of these landscapes, but in fact, it will more experience the vast vigor of the Loess Plateau to see the panorama than to only see the locals. At present, by virtue of fire balloon, helicopter and other tools, few tourists can realize that, but for the mass, the economic and feasible method is to sculpture these physiognomy landscapes and let tourists easily to realize this target.

4.3 The tourism landscape in the White Deer Plateau can be enriched

The loess sculpture garden can form special tourism attractions. Furthermore, it can be combined with many landscapes such as mountain, water, forest, farmland and cultures to form tourism products with different layers and types. When tourists study the science knowledge about loess, they can make man with clays, carve by loess, experience real earth cave-house, enjoy the picking interests in the gardens around the landscapes, and swim in the water scenery area, which can not only leave tourists, but drumbeat the tourism issue of the White Deer Plateau.

4.4 The social and economic development of the White Deer Plateau can be driven

As the important part of Xi'an, the White Deer Plateau will influence the total development level and the regional harmony of Xi'an in the economic development. But the White Deer Plateau is still the area giving priority to the agricultural production and management, and the industrial development lacks in resources and bases. Though the tourism industry has abundant resources, but the scale effect of the development can not be formed at present, and the local residents have few employment opportunities, and the social and economic development is relatively lagged. Therefore, the development, construction and management of the "loess sculpture garden" will offer more employment opportunities for local residents, and improve the social and economic development of the White Deer Plateau.

5. Advantages and characters to construct the loess sculpture garden

The advantages and characters to construct the loess sculpture grader are very obvious as follows.

5.1 Unique loess plateau in the world

The Chinese loess plateau is unique in the world, and it is located from the north Yinshan Mountain to the south Qinling Mountain and from the west Riyueshan Mountain to the east Taihang Shan, traversing the territories of Qinghai, Ningxia, Gansu, Shannxi, Shanxi and Henan. It covers an area of approximately 640,000km². The depth of the loess sediments is in 100m~200m, and the deepest depth is above 500m, located in the Jingyuan of Gansu Province. The types of the loess physiognomy are diversiform, and the landscapes are beautiful, and the loess stratum grows completely, and it is the unique physiognomy landscape area in the arid and semi-arid region of the world.

5.2 The largest loess physiognomy in the world

The physiognomy forms of the Loess Plateau are diversiform, and the ravines on the ground are located vertically and horizontally, which is called by the "fragmented landform". There is the largest loess plateau, Dongzhi Plateau, in the world, and its longest length from north to south is 110km, and its longest length from east to west is 50km, and its area is about 910km². And there is the most typical loess plateau in the world, Luochuan Yuan, and it not only has large-scale physiognomies such as loess tableland, loess ridge, loess hills and streams, but small-scale physiognomies such as loess coast, loess landslip, loess suspended gullies, loess water-falling cavities, loess bridges, loess poles and loess walls which possess special sculptures and appreciation values. Luochuan Plateau also has clear loess sections, continuous and complete stratum, clean age-old soil layer and higher learning value, and it has been developed as the national geological park. There is the White Deer Plateau which is concerned by global literature fans. And there is the second largest rive in the Loess Plateau, the Yellow River, which cuts the loess plateau and helps to form the special river physiognomy landscapes including the gorges and curving flows. The Yellow River has about ninety nine bending flows,

and the most beautiful one is the Jinshan Gorge which generates the world-famous Hukou Waterfall. The loess physiognomy landscape is the most core part of the loess tourism.

5.3 Specific humanistic landscape in the loess plateau

The special natural environment of the Loess Plateau gestated special loess cave dwellings, typical agricultural terrace landscapes, full-bodied dietary culture and dress culture, wedding custom, funeral custom, abundant traditional arts and cultures such as civil arts and crafts, civil dances and songs, civil musical instruments, civil music and civil amusement, and these multiform and original humanistic landscapes are special in the Loess Plateau, and tourists can experience different lives in different regions in the Loess Plateau, so these landscapes possess specific tourism attractions.

6. Feasibility to construct the loess sculpture garden

6.1 The loess wonder is famous in the world, and it has large attraction

There is the world-famous Loess Plateau in China, and the loess physiognomy landscapes here have the largest-scale one in the world, and the most complete loess stratum section landscape which grows best in the world, and the corrosion landscapes where the soil is corroded worst in the world, which can largely attract domestic and foreign tourists, and are the resource base to construct the loess sculpture garden. The White Deer Plateau belongs to the loess plateau with deep soil stratum of above 100m, so there are abundant material bases to construct the loess sculpture garden. The loess sculpture is the important part in Chinese ancient sculptures, and the soil sculpture located in the Shanglan Village of Taiyuan is the ancient rare soil sculpture production in China, but most of these ancient soil sculptures were made by original soil, and the soil quality is loose and easy to be eroded by rains and they are difficult to be conserved. But the red clay in the White Deer Plateau is very striking, and because these soils contain more clay, so their rigidity is higher, and they can bear more pressures, and the laterites can be used to sculpture. Comparing with the manufacturing techniques of sand sculptures and ice sculptures, not only these soils are easy to be sculptured, but the sculptures created by them can be conserved longer, and the relative construction costs are lower.

6.2 The traffic is very convenient

Convenient traffic is the necessary condition for most successful tourism items. The White Deer Plateau is located in the southeast Xi'an City, connecting with round-city highways, Hu-shan highway, Lian-huo highway and Xi'an-Yanliang highway, which can be linked with the roads arriving to the Plateau, and there are many public lines such as Route 406 in Xi'an connecting with the White Deer Plateau, and the drive time to the White Deer Plateau is only 30 minutes.

6.3 It is near with the world historical and cultural city, Xi'an, and the passenger flux is large

Another necessary condition of the successful tourism item is the selection of the position which decides the passenger source. Though Luochuan Loess Plateau has strong attractions for exterior provincial tourists, but the loess sculpture garden should not be constructed in Luochuan but in the White Deer Plateau because of the passenger source market. The White Deer Plateau abuts against Xi'an City, and it is the important space to develop the tourism for Xi'an. Xi'an is the historical and cultural city with reputation in the whole world, and it was the capital of 13 dynasties in the history, and it has been the world-famous tourism city. On the other hand, in thousands years' development of the historical and cultural city, Xi'an has been a comprehensive metropolis, and it possesses dense population, high economic development level and strong resident consumption ability, and it is one of main tourism consumption cities in China. Numerous local tourists and many foreign tourists will be the target market of the White Deer Plateau Loess Sculpture Garden.

6.4 The demand of the science and technology tourism is more and more intensive

As a special tourism activity on higher layer, the science and technology is increasingly favored by people. At present, Chinese public have higher concerned degree to the science and technology knowledge, especially for the selections about the science and technology resources such as the biology, geography and astronomy (Liu, 2008, P.34-39). Therefore, the White Deer Plateau should grasp the opportunity, fully utilize many research result of the loess, establish the loess sculpture garden, fully develop the loess popular science tourism and fulfill people's demands and desires.

6.5 The White Deer Plateau has good reputation

The reputation has been the key factor to influence the tourism item marketing. If one region has good and high reputation, tourists will more easily accept and believe in the tourism drumbeating and promotion. The saga novel, "White Deer Plateau" wrote by the modern famous writer, Chen Zhongshi, made this silent land to be well known by the world, which has established firm base for the marketing of the loess sculpture garden tourism.

7. Main contents to construct the loess sculptures on the White Deer Plateau

The construction of the White Deer Plateau loess sculpture garden must be implemented under the concept of the sustainable tourism development, taking the features of science, culture, location and characteristic as the principles.

The garden including the Loess Garden, the loess physiognomy landscape, the loess stratum, and humanistic loess landscape and the loess amusement should be the popular science topic garden with specific topic, multiform types and abundant contents.

7.1 Sculpturing the landscapes of the Loess Plateau

To make domestic and foreign tourists comprehensively perceive the Loess Plateau, the Loess Plateau must be sculptured first. First, the remote sensing image of the Loess Plateau can be used to instruct the concrete sculpture design, and clearly depict the landform characters such as loess tableland, loess ridge, loess hills, river, channel and mountains to present the total landscape formation of the Loess Plateau. Second, the scientific knowledge of the Loess Plateau should be transferred to passengers, and the knowledge include the source and formation of the loess, the basic character and utilization values of the loess, the forming reason, range, area and environmental character of the Loess Plateau. Of course, many technical measures such as 3D cartoon, visual reality technology and traditional color picture with lively scientific explanation can be adopted to enhance the newness sense and the amusement feature.

7.2 Sculpturing the landscapes of the loess physiognomy

In the loess physiognomy landscapes, the typical and representative physiognomy landscapes with large area and higher reputation, well combining with other loess landscapes should be selected to sculpture. First, Dongzhi Plateau, Luochuan Plateau and White Deer Plateau should be sculptured, and there are above 2000 ravines at the sides of the Dongzhi Plateau to run out the hinterland of the Dongzhi Plateau, and the ravine which is nearest with the plateau is only 50 with the heart of the plateau, which can make tourists know not only the characters and changes of the Dongzhi Yuan, but the serious influences of human activities to the water and soil losses in the Loess Plateau to enhance their environment-protective consciousness. The loess tableland, loess ridge, loess hills and channels in the Luochuan Plateau grew well, and the small-scale physiognomy landscapes are complete, so the sculpture could help tourists form a clear understanding for the complete growth process of the loess physiognomy landscapes. The White Deer Plateau is the largest loess plateau near Xi'an, and the historical plateau and the cultural plateau, and one of important reasons is that the novel of "White Deer Plateau" pushed it to the world. Finally, the Yellow River and its special river physiognomy landscapes should be sculptured to show the forming process of the river physiognomy. The sculptures of the loess physiognomy can show not only various large-scale physiognomies, but small-scale physiognomies landscapes, and the target is to let tourists know the types, characters, causes, growth process of the loess physiognomy, and form a complete and scientific cognition to the forming and changing process of the Loess Plateau.

7.3 Sculpturing the section of the loess stratum

The important meaning to sculpture the loess section is to make tourists know the scientific knowledge about the loess and the past environment change. First, the typical loess-paleosol sequence of the Loess Plateau should be sculptured, and its core intention is to transfer the ancient climate change, soil, vegetation, sand storm, groundwater and other geological environment information since the Fourth Age reflected by the different strata in the loess section to tourists, and the key is to set up the stratum marks and corresponding explanation words. Of course, because the White Deer Plateau also has disclosed loess sections with continual, complete, clear and well-conserved stratum, so 2 or 3 spots in the Plateau can be selected to show, and make tourists to have the sensitive cognitions to the relationship between the loess and the environment. Tourists can observe, look, touch and feel these landscapes, and combining with easy and facetious language explanations, they will acquire a clear and comprehensive understanding to the relationship between the loess and the environment.

7.4 Sculpturing the humanistic landscape of the Loess Plateau

The humanistic landscape sculptures in the Loess Plateau include three parts, i.e. the loess cave-house, the sloping terrace and the folk-customs. Because the loess folk-custom landscapes are lively landscapes which have strong participation feature and experience feature, and the sculptured folk-custom landscapes have not these advantages, so when the loess folk-custom is shown, the loess cave-house yards can be taken as the background, the people's real livings in different regions of the Loess Plateau can be taken as the references, and the loess folk-custom scenes with certain characters can be constructed to show the civil arts and crafts, traditional dietary cooking, civil songs and dances and civil music, and protect, dig and inherit the traditional cultures of the Loess Plateau. According to the story of the saga novel "White Deer Plateau", the farming, grinding stone, fowl breeding, daily customs, amusement, traditional Shehuo and other life scenes can be recovered and developed, and some typical story scenarios can be sculptured to fulfill human demands for the "White Deer Plateau".

Finally, to enhance the tourism interests of the loess sculpture garden, the design of the amusement item is the necessary part of the garden construction. But because the items of the loess amusement are less, so the water and rural tourism resources should be integrated and developed. Tourists can not only make man and sculptures with clay, but participate in the water amusement items such as yacht surfing, yacht sightseeing, fishing, swimming and handle boat, and the farming activities such as picking.

8. Conclusions

First, the loess physiognomy in the Chinese Loess plateau has large tourism value, and it is not only the excellent site to implement the geological research, but the important resource to develop the popular science tourism. At present, the tourism development of the White Deer Plateau is still in the initial stage, and the tourism products are single, and the characters are not prominent, and the topic image is not concrete, so it is necessary to construct the loess sculpture garden. The sculptures can not present the micro physiognomy landscape, but show macro physiognomy model, which offer effective approach to appreciate vast loess physiognomy landscapes. The loess sculpture garden can drive the large development of the Xi'an White Deer Plateau tourism industry, and more important, it can create a new mode of the geological popular science tourism.

Second, it has obvious resource advantage and characters to construct the loess sculpture garden, which can completely and systematically popularize the scientific knowledge about loess, and visually show the loess landscapes of the Loess Plateau. The White Deer Plateau is near the Xi'an City, and convenient traffic and entrances, large passenger flux and high reputation are all advantageous and necessary conditions to construct the loess sculpture garden.

Third, the loess sculpture garden will sculpture the largest loess plateau in the world and the largest loess plateau in Shannxi, the Yellow river and other large-scale river physiognomies, the soil erosion and erosion landscapes to show the largest loess physiognomy landscapes in the world; and sculpture loess stratum section landscapes grew best in the world and the specific humanistic landscapes of the Loess Plateau in the Loess Plateau to enhance the appreciation values of the loess landscapes, deeply dig its scientific and educational values, combine the appreciation feature with the popular science-based feature, and make it become the hotspot of the tourism and the based of the popular science education.

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Research and Application of China Well Information System Based on ArcIMS

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Abstract

Well data is the important and basic data for geology work. In order to develop and utilize well information resources more efficiently, the present paper attempted to use ArcIMS 9.0 as development platform to realize functions of WebGIS, based on C/S(Client/server) or B/S(Browser/server), utilize ASP(active server page) and ADO (active data object) to write codes for updating and maintaining attribute data, achieve share and exchange of well data on internet in combination with ActiveX. At the same time, the present paper resolved the problem of Chinese display.

Keywords: ArcIMS, ActiveX, Well data, WebGIS, Internet

1. Introduction

Currently, management mode of well data has been relatively passive and backward, and storage medium of part data have always been paper carrier or data entity. Works on the archives information processing have been less developed, and there have been great limitations on the preservation, utilization and service. Information was less available, and tough to lookup with low efficiency and difficulty to manage and maintain. It was tough to meet the requirement of open and diversified development on the exploitation and utilization of well data imposed by users, which affected the utilization of file data. Well file data is significant information, and important basis for the planning, management and rational utilization of all kinds of well. A specific geological work, was always to investigate all existed geological data at large, and finally form new geological data, again and again, and it would become huge social wealth of human being(Xin, 2008). Additionally, well data possessed the characteristics of high cost, large quantity, complicated types, huge potential of social and economic benefits, and have been extensively applied in the areas such as earth science, mineral investigation and development, environmental protection and so on. Well file data was precious information resources, and should be promptly undertaken development and utilization.

Along with the development of geographic information system(GIS) and database technology, especially the convenience of ArcIMS on establishing atlas, developing web pages with links to atlas and managing map website, and the application of its architecture and function in publishing maps, data and meta data, all afforded the likelihood of realizing the united storage and visual management of well file data(2004). In the present paper, we combined the strong advantages of ArcIMS and ASP, aiming at the practical situation of well data of geological industry, and devised a set of concise and efficacious data management scheme. According to the well attribute data and vector base map files, Webgis navigation main interface was produced; Code was written by ASP, and data transmitted from Webgis navigation main interface was used to realize the query, search and orientation of geological data. According to the security requirements and degree of importance, relative data was used by the combination of C/S and B/S.

2. System overall design

2.1 Outline

This system included parts of database server and client application. Database server mainly realized the untied storage

of spatial data and attribute data, among which spatial data contained geographic base map and well position chart, and attribute data included static and dynamic information. Client part belonged to data updating system, used as the maintenance and application of data.

2.2 Overall structure design

This system adopted the development mode with the combination of C/S and B/S, and could be disposed to different system structure according to the importance degree of well file data. C/S reasonably allocated assignments to the client and Sever, and made up the deficiency of ASP in security. In combination with the object of ASP with no necessary compiling, without problems of browser compatibility, component function of ActiveX Server could be extended, and database access could be convenient (using ADO component) with advantages of hiding program code and convenient compiling(Luo,2004, PP.58-62). It lowered the expenditure of system communication, and a host of work could be submitted to server after processing in client, which exerted the processing capability of client and embodied the characteristics of prompt response in lan.

B/S was a supplement and amelioration for C/S, and user interface carried out through browsers, which alleviated the workload and cost of system maintenance and updating. In combination with the advantages of C/S, such as security, celerity and nicety in Lan, and those of B/S, such as opening, convenience, information share in high grades and so on, server was decomposed into data server and application server, forming the architecture with three layers, which was depicted in Figure 1. B/S could differentiate data access operation and application model, using ArcSDE as the GIS application server in C/S, IIS as Web server, through the data filtering of server side, less network traffic was obtained with rapid execution speed. In combination with better system structure of ArcIMS, information transfer mechanism, and organization and spatial distribution of multi-source data, stability and efficiency of the whole system was guaranteed(Li, 2003).

2.3 Function design

Data updating system: main objective was to manage well file data, and through data updating, renovate and maintain well information and corresponding file data at any moment, keeping the real-time of information.

Application system: application function such as inquiring about, calculating, browsing and downloading well file data.

General function: general functions GIS possessed such as zooming in and out and rambling the atlas, data location and lookup. As well as "eagle-eye" function, namely that index map in the indicated map of atlas frame. Users could easily know the relationship between the present map and panorama, and immediately locate their concerned positions.

3. Key technology

3.1 WebGIS

Main technical methods such as CGI(Common Gateway Interface) and browser plug in for WebGIS had limitations, for instance zoom-in and -out of client images were tough, and data excessively fasten on the client. ActiveX was the standard developed with attempts to adapt, based on OLE(Object Linking and Embedding) standard, and offered public frame for extending Internet Explorer function of Microsoft Web. ActiveX was a software module used for accomplishing certain assignment and information communication, processing GIS data and completing GIS analysis, and could be used by any programming languages or application system supporting OLE standard(Rohit, 2003). ActiveX was one of the four customization procedures ArcIMS provided, and ActiveX connector was used to link web server and ArcIMS application server. Map could be added to ASP or Visual Basic, and based on Internet GIS ActiveX, processing and display of GIS data were done depending on GIS ActiveX. ActiveX closely hanged together with web browser flexibly and seamlessly. Under the normal condition, GIS ActiveX was contained in the HTML codes, and obtained through the reference label of <OBJECT>(2003).

ASP have substituted CGI, ISAPI, JDBC and so on due to its dynamic high efficiency and easy alteration. It not only combined HTML pages, Scripts language and dynamics server component, but also made all processing accomplished in the server. Additionally, the output of ASP files was suitable for the HTML of Web browser. HTTP(Hypertext Transfer Protocol) adopted stateless mechanism in order to enhance work efficiency of server, but had no memory capability for transaction process, which caused that each connection needed more information transmitted and attenuated work efficiency to some extent. Therefor, when developing system ASP, such problem could be solved by ASP implicit object Session. Taken together, we implemented WebGIS technology by the combination of ASP and ActiveX in the present paper(Rohit).

3.2 Multi-source and distributed database technology

ADO technology linked general relational database into the system, extended data source for system, and afforded broader data support for making thematic maps. Its cardinal advantages were easy to operate, high speed, low memory expenditure and less occupied disk space. Moreover, it had the function of remote data service(RDS), transmitted data from server to client application procedure or Web pages during one two-way process by RDS, implemented data

process in client and then return the updated information to server. As for setting system user authority and designing query module, it applied the combination of ASP and database access technology typically. ArcSDE(Spatial Database Engine) was GIS channel between ArcGIS and relational database, and geological database server on the basis of relational database. Application of ArcSDE could realize seamless integration of spatial data and attributed data, which could not only accelerated the query of system, but also facilitated managers to manage and maintain database. Accordingly, we applied the technological mode of Access+ArcSDE, which could store spatial data, attributed data and well file information in different servers, erect multi-source database. Data transmission bottleneck would not occur just due to excessive dependence on one server. It would form a flexible data system, which offered technology guarantee for distributed global share(Liu, 2009).

3.3 Chinese display technology

Due to operating system version and damage and deletion of related files, character sets of server and client differed, and Chinese display in ArcIMS was irregular. ArcIMS atlas service customization, management and issued software were all based on the function of JRE(Java Runtime Environment). During running, when JRE couldn't parse Chinese, Chinese fonts in softwares such as Author were disorderly codes or no display, and thus JRE Chinese display was required to collocate(2008). One more situation, Chinese character sets of database didn't match those of ArcIMS, for data was read from database, and thus Chinese display in ArcIMS could be also irregular. Manifestation and solution were as follows:

3.3.1 Disorderly codes in web pages(Chinese display of ArcIMS in html viewer was disorderly codes), and codes were "?", panes, fonts similar to Chinese-traditional characters and so on. Occurred positions were mainly filed name, and layers and lists of query. Solutions were as follows:

A. Edited aimsXML.js file in the working directories of javascript. Replaced var charSet="ISO-8859-1"by var charSet=one certain Chinese character sets. For example: var charSet="GB2312".

B. Edited mapFrame.htm file in the working directories of viewer.htm. Edited the following line: <meta http-equiv="Content-Type" content="text/html; charset=ISO-8859-1">. Replaced the previous described ISO-8859-1 by character sets required, such as GB2312.

C. Acquiescently, ArcIMS HTML Viewer used Arial font. In order to display fonts exactly, edited corresponding part of ArcIMSParam.js file:var legFont="Arial"; Replace Arial by corresponding system fonts, such as var legFont="blackbody".

3.3.2 Chinese label disorder codes in atlas, and main codes were panes which appeared in atlas(namely pictures returned from ArcIMS server). Solutions were as follows:

A. Checked the letters and found out whether they were variable transmitted from page inner to set up a dynamic layer. If so, see whether those letters during the period of transfer were normal, or the issue was coding.

B. If not, examined the fonts of these disorder code fields of the map using designer. Looked up in the font directories of corresponding computers, and found out whether there was such fonts or not. Issues occurred due to such fonts.

C. Installed the font, or replace it by a font already existed in your computer.

Excluding approaches of setting character sets to make Chinese information normal, there was still another way to attained such goal, such as chinesization of ArcIMS. Firstly, downloaded chinesization files of ArcIMS in ESRI Chinese website instead of corresponding files. Mainly five modules for chinesization were Manager, Viewer, MetadataExplorer, Esriadmin, management tool application program and ArcExplore. Management tool application program included ArcIMS Administrator, ArcIMS Author and ArcIMS Designer.

4. Function realization

4.1 Multi-source database

Database was the basis of the present system, including attribute and spatial database. According to the situation, these data could be disposed at different servers, which was in more favor of data update and transmission efficiency.

Information of attribute database in relation to well archives data were mainly well coordinate information, well basic information, well sort information, well data information and well data sort information.

Spatial database used 1:2,500,000 Chinese provincial administrative map as backing, and was published using shapefile format. Map layers published included Chinese administrative division base map, Chinese coast map with provinces, Chinese maritime space map, Chinese main sea area map and Chinese well location map. Users could browse and inquire about properties of layers through activating operation, and put these data through the modules of ArcIMS management tool such as Author, Administrator and Designer to process, which could possibly form web pages. For easy display, part content was selected to give a demonstration.

4.2 Data acquisition

GIS database server located at the back end of prototype system, and was storage base of system original geological information, with functions of managing GIS original data, responding the request imposed by ASP engine and sending generated HTML pages to WebGIS server(IIS). ArcIMS made well attribute and spatial data formed corresponding WebGIS web pages and files, and modified the generated related files(consulting 3.3 Chinese display technology), which made system able to identify Chinese characters. Opened the hyperlink function, clicked on wells in WebGIS pages(Dave, 2004), used well name as query condition, and then corresponding ASP pages ejected. Just like this, we could manage and apply archives data in these pages. Codes were as follows:

4.2.1 The following codes were the well names to take out and click when WebGIS pages shifted to ASP.

```
url=Request.ServerVariables("SCRIPT_NAME") `Return to relative path of present WebGIS page
SearchChar = StrReverse(url) `Return to the character string in opposite systematic arrangement of relative path
MyPos = InStr(1,SearchChar,"/",1) `Acquire the character length of well name if mypos>1 then
mypos=mypos-1 `Acquire the wall names by each character
end if
str1= Right(url, MyPos) `Well name, as the query condition of ejecting ASP pages
```

4.2.2 The following code was to link and open well archives information base.

```
Set conn = Server.CreateObject("ADODB.Connection")
DBPath = Server.MapPath("Well.mdb")
conn.Open "driver={Microsoft Access Driver (*.mdb)};dbq=" & DBPath
```

5. Conclusions

The present paper introduced the design and application of Chinese well information system based on ArcIMS. On the basis of ArcADE and Access, we set up multi-source database, and realized the application and management of well data information using ASP, ActiveX, ADO and so on under the premise of a host of data share. According to security and practical requirement, C/S or B/S could be applied, which realized the unified integrative display of multi-source spatial data and functions of graphics interaction query and access between vector and raster data under the network environment. This intuitive and efficacious interactive visual environment was of great significance to the visual share of complex multi-source spatial data.

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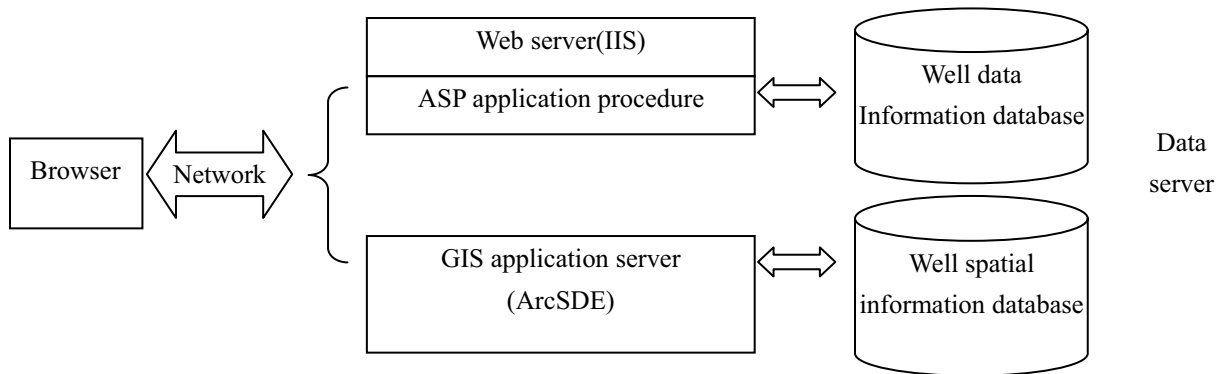


Figure 1. Overall architecture

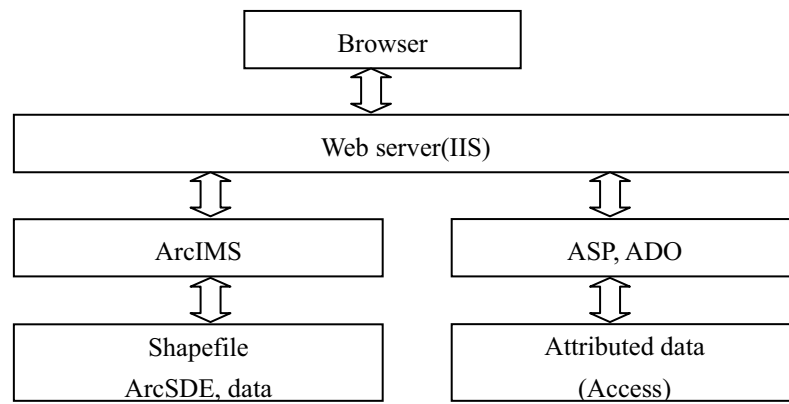


Figure 2. Database schematic diagram

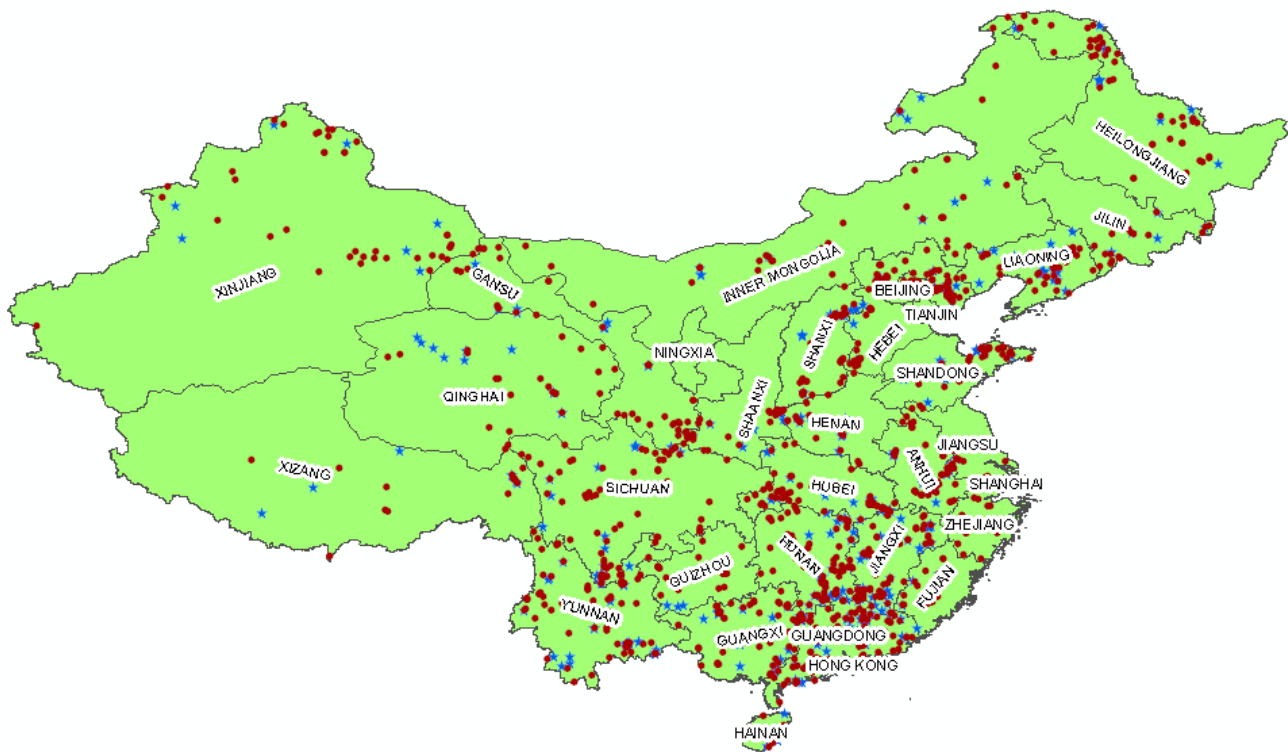


Figure 3. Well location distribution map



Experimental Study on the Mechanics Character of Lava in the Area of Xujiaweizi

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Abstract

The Xujiaweizi rift in the north of Songliao Basin is the largest volcanic gas reservoir in China, and because the mechanics character of lava largely influences the production and development of the oil field, so it is necessary to make clear the mechanics character of laves in this area. After analyzing the lava lithology of the Daqing Xujiaweizi, taking the rock mechanics and the elastic mechanics as the theoretical base, six kinds of representative lava mechanics characters in this area are tested in the laboratory, and relative basic mechanics parameters are obtained, which can exert important function for relative engineering design. The test results show that the lavas in this area are representative brittle rocks and the rock fracture mainly is brittle failure, and with the increases of the burial depth and the confining pressure, the rocks present character of plastic failure. The research results will play a very important role in the volcanic gas reservoir exploitation in Daqing Xujiayanzi.

Keywords: Rock mechanics, Lithology, Lava, Experimental study

1. Introduction

With the developments of the petroleum industry and the oil-gas field exploration, large numerous of lava oil-gas reservoirs have been found and the oil-gas flows with commercial values have been obtained in China. The Xujiaweizi rift in the north of Songliao Basin is the largest volcanic gas reservoir in China, and the proved reserves have achieved above hundred billions cubic meters (He, 2008, P.463-471). The exploring practice shows that the lava-buried depth of this area generally is 3000m-5500m, and the north of the rift mainly includes intermediate-basic rocks (andesites, basalt-andesites) and the south of the rift mainly includes intermediate acid rocks and acid rocks (dacites and rhyolites). Because of the differences of the stratum lithology, the mechanics characters of stratum rocks are different, which will influence the exploration and development of the oil field. Therefore, it is necessary to systematically study the mechanics characters of lava stratum. The relative research can not only offer powerful technical support to enhance the drilling speed of well for Daqing Oilfield, but have very applicable values for the lava stratum drilling in other oilfields.

2. Analysis of stratum lithology

The lavas in the Xujiaweizi rift belong to the volcanic association from the Late Jurassic Epoch to the Early Cretaceous Epoch ($J_3 - K_1$). And the lavas are on the base of unconformity permo-carboniferous system ($C - P$) opimetamorphic rock series, and are covered by the Mesozoic Era Cretaceous (K_1) Dengloulou group (K_1d) and Quantou group (K_1q) sedimentary rocks. According to the actual situation of the deep lava stratum in Xujiaweizi, and the principle of "if the characters of measured wells are similar, the geological meanings are same (Ran, 1996)", the lavas in this area can be divided into six representative rock types, i.e. basalt, andesite, dacite, rhyolite, tuff and breccia (seen in Figure 1).

3. Experimental study of lava mechanics characters

The experiment is the base of all scientific researches. To measure the basic mechanics characters of lava by certain

testing method and measures is one of main contents of the lava mechanics study. The experiment research of the rock mechanics characters includes two aspects (Lou, 2006, P.94-104), i.e. the distortion character of rocks, and the intention character of rocks. The experiment research of rock distortion means to study the distortion rules of the rock sample under various loads, such as the elastic distortion, the plastic distortion, the viscosity flow and the failure rule, and it reflects the mechanics attribute of rocks. The experiment research of intention character is to study the relationship between the maximum stress (limit of intension) and the relationship between the stress and the fracture of the rock sample, and it reflects the ability to resist the fractures and the fracture rules of rocks.

3.1 Experiment equipments

- (1) TZ-1 rock core catcher (the drilled rock core: $\Phi=25\text{mm}$, $L=80\text{mm}$).
- (2) Three-axis rock testing system (MTS-816 Testing System). Take the rock core ($\Phi=25\text{mm}$, $L=50\text{mm}$), and put the plastic enveloped rock core in the confining pressure room, and nip the strain gauge, and hood the confining pressure box, and exert axial load until the rock core is destroyed and record the failure pressure. The stress of rock failure is the pressive strength of the rock.
- (3) Multi-functional rock drillability tester made by the Instrument Factor of China University of Petroleum (East China) (the drilling pressure: $890 \pm 20\text{N}$, rev: 55 ± 1 (r/min), pre-drilling depth: 0.2mm , work drilling depth: 2.4mm , displacement differentiation: 0.01m , timing precision: 0.01s).
- (4) Rock rigidity tester made by the Instrument Factor of China University of Petroleum (East China) (the diameter of bit: 2mm , the axial pressure: $0-5000\text{kg}$, the displacement range: $0-10\text{mm}$).

3.2 Testing of rock mechanics parameters (Yang, 2001, P.55-58)

- (1) Single-axis pressive strength σ_c :

$$\sigma_c = P / A$$

Where, P (N) is the failure load of rock sample and A (mm^2) is the original transect area of the sample.

- (2) Elastic modules E : it can be obtained by the stress-strain curve in the condensation experiment of the standard rock sample, i.e.

$$E = \frac{\Delta \sigma_z}{\Delta \varepsilon_z}$$

Where, $\Delta \sigma_z$ (MPa) is the increment of axial stress and $\Delta \varepsilon_z$ (m) is the increment of strain.

- (3) Poisson ratio μ : it is the ratio of the transverse relative condensation and the lengthways relative stretch, i.e.

$$\mu = \frac{\Delta d / d}{\Delta L / L}$$

Where, L and ΔL (m) respectively are the rock length and the lengthways relative stretch, d and Δd respectively are the rock diameter and the transverse relative condensation.

- (4) Drillability K_d : it is related with the time needed to drill into the regulated depth of the measured rock T (s), i.e.

$$K_d = \text{Log}_2 T$$

- (5) Rigidity K_h : it is the load on unit area of the contact face when the brittle failure happens, i.e.

$$K_h = P / S$$

Where, P (N) is the axial load, and S (mm^2) is the bottom area of the bit.

3.3 Experiment results and discussions

Thirteen representative rock cores in Daqing Xujiaweizi are selected as the research object in the article, and their mechanics parameters are tested in the labortory one by one (seen in Figure 1). Figure 2 is part of the stress-strain curve of rock core.

From Table 1 and corresponding core stress-strain curves, the texture of lavas in this area is hard, and the drillability is bad, and the grinding character is strong, and the pressive strength is not even, and these lavas belong to representative brittle rocks, and the fracture mainly is brittle failure. For the rhyolites, the drillability value is above class 9, the stratum rigidity is in $3000\text{MPa}-5000\text{MPa}$, and the pressive strength is in $110-150\text{MPa}$, which indicates that the rocks are hard and dense, and the drillability is bad. For the tuffs, the drillability value is in class 6-class 10, the stratum rigidity is in $2000\text{MPa}-2800\text{MPa}$, and the pressive strength is in $80-120\text{MPa}$, which indicates that the rigidity of the rocks is high, the rocks are hard and dense, and the drillability is bad. For the andesites, the drillability value is in class 7.0-class 8.5, the stratum rigidity is in $2500\text{MPa}-4000\text{MPa}$, and the pressive strength is in $80-130\text{MPa}$, which indicates that the

rigidity of the rocks is high, the drillability is bad, and the passive strength is not even. For the breccias, the drillability value is in class 5.8-class 6.5, the stratum rigidity is in 1300MPa-2000MPa, and the pressive strength is in 65-80MPa, which indicates that the rigidity of the rocks is high, and the passive strength is not even. For the basalts, the drillability value is about class 9, the stratum rigidity is in 4000MPa-4300MPa, and the pressive strength is about 110MPa, which indicates that the drillability of the rocks is bad and the lithology is hard and dense. For the dacites, the drillability value is about class 8.7, the stratum rigidity is above 3000MPa, and the pressive strength is about 100MPa, which indicates that the drillability of the rocks is bad and the rigidity is high. Therefore, when designing the lava reservoir waterpower fracture and selecting bit model, these differences should be fully considered to design reasonable construction parameters and effectively enhance the rev of mechanical drill. In addition, from the fracture surface of experimental sample, most lava presents the characters of brittle failure and cutting failure. And with the increases of the depth and the confining pressure, the plastic failures occur, which could offer important references to analyze the fracture waterpower crack formation and the natural crack formation of the oil field.

4. Conclusions

- (1) The lithology of lavas in this area is complex, the texture is hard, the drillability is bad, the grinding character is obvious and the pressive strength is not even, and the lavas belong to representative brittle rocks.
- (2) The fracture of lavas mainly is brittle failure, and with the increases of depth and confining pressure, the plastic failure occurs, this character could offer important references to analyze the waterpower fracture crack formation and the natural crack formation of the oil field.

References

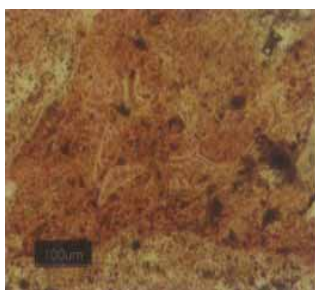
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Table 1. Room rock mechanics parameter testing results of Daqing Xujiaweizi

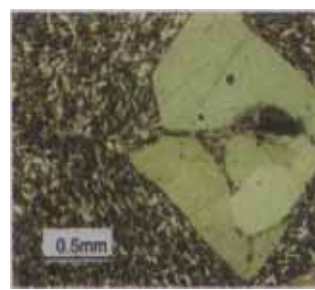
No. of Core	No. of Well)	Depth(m	Lithology	Quality (g/cm ³)	Modulus of elasticity (GPa)	Poisson ratio	Max. of drillability	Rigidity (Mpa)	Pressive strength (Mpa)	Rock fracture
1	SS 2	3005.20	Offwhite rhyolite	13.2	11.5	0.14	9.12	4 779.10	128.9	Brittle failure
2	SS 2	3279.36	Green-gray tuff	11	10.4	0.22	7.51	2 220.63	89.4	Cutting failure
3	DS 1	3320.54	Celadon rhyolite	17.9	16.3	0.34	>10	5 093.27	134	Brittle failure
4	DS 1	3501.36	Andesite	15	9.9	0.05	8.11	2 879.97	97	Brittle failure
5	DS 1	3771.00	Rhyolite-dacite	14.3	10.4	0.24	8.78	3 748.10	112.7	Brittle failure
6	SS 5	3878.64	Gray tuff	10	7.5	0.11	6.4	2 342.99	78.3	Cutting failure
7	SS 5	3981.54	Gray tuff	11.1	8	0.26	6.65	2 000.25	80.2	Brittle failure
8	XS 3	4324.39	Tuff-breccia	9.9	6.3	0.17	6.86	2 002.60	74.3	Plastic failure
9	So-S 1	4811.01	Andesite	17	7.2	0.26	7.3	2 801.30	86.5	Brittle failure
10	So-S 1	4980.70	Volcano breccia	10.8	5.9	0.09	5.82	1 512.44	65.3	Plastic failure
11	So-S 1	5201.72	Andesite-basalt	13	9.3	0.23	8.93	3 790.01	115.2	Brittle failure
12	PS 1	5280.30	Amaranth andesite	13.4	8	0.21	8.38	3 963.20	113.3	Brittle failure
13	PS 1	5343.65	Tuff	11.9	7.4	0.3	7.2	2 713.70	97.3	Plastic failure



SS 6 Rhyolite (orthogonal) 3508.38m



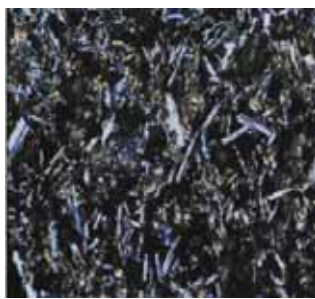
XS 6 Tuff (single-deflection) 3615.41m



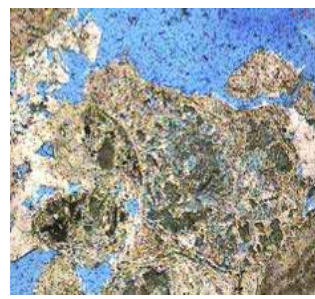
XS 5 Dacite (orthogonal) 4051.52m



XS 4 Andesite (orthogonal) 4258.4m



XS 1 Basalt (orthogonal) 3779.4m



XS 8 Volcano breccia (single-deflection) 3761.2m

Figure 1. Representative Lava Lithology Characters of Xujiaweizi

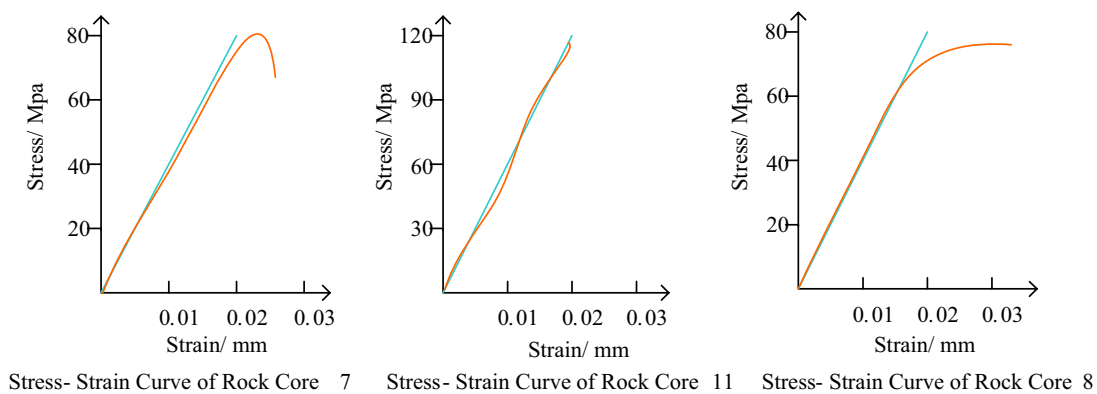


Figure 2. Stress-strain Curve of Rock Core



Modelling Genesis of Intracratonic Chains Related to Tectonics Inheritance. Case Study from Gafsa Basin (Southern Central Tunisia)

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Abstract

Tectonic inheritance is a concept proved by the importance of tectonic phase's variation during time. It is related to reactivation in compression of old normal faults. In our study we will focus on Gafsa basin that is an example of intracratonic chain. The tectonic data confirm that it is affected by several tectonics phases; they began with Triassic distension continuing to Cretaceous and followed by resumption in compression according to NW-SE direction during alpine phase. Structural reliefs observed in Gafsa Basin are interpreted according to the "fault related fold" theory, by using the model of 'fault propagation fold'. The applications of this model will show a decollement level within the Triassic series. In addition, an important deformation will be identified while approaching to faults. The data elaborate from field confirm the role of these faults in the interpretation of tectonic heritage and development of intracratonic chains in Gafsa Basin.

Keywords: Tectonic inheritance, Intracratonics chains, Fault related fold, Fault propagation fold, Decollement level

1. Introduction

The tectonic inheritance was the object of several studies showing the important polyphase deformation of the tectonic activities during the time. The history of the reconstruction of continental platforms in globe is related to more than one tectonic activity; it begins with the extension given by the decomposition of Pangea according to the great old normal faults. This period was followed by the dominance of compression and installation of large orogenic relief.

The problem is to model this tectonic inheritance and interpret the detached foreland structures always in Consideration with the influence of extensive heritage. For a better interpretation it is important to study the structures on the front of orogens, and more precisely on the level of vast fields of certain external zones.

In the external orogenic zones the interpretation of brittle deformations can be solved according to the notion of ramps that is developed by the theory of balanced cross section. The application of this model is verified only when the mode of deformation accompanying the movement on the ramp is checked Menard (1988).

Among these modes we can quote "fault bend folding" developed by (Dahlström 1970; Suppe 1983); hence the model of 'fault propagation fold', (Suppe and Mdwedeff 1984; Suppe 1985 and Jamisson 1987). In addition the model of listric faults and concentric folds Dahlströme (1970, 1990) and finally the composite mode of "chester", Chester (1990). In the application of these models it is necessary to check the geometry of the external zones of chains to a better interpretation of the suitable style of deformation. What summer proven by Mercier (1990, 1995).

The tectonic heritage resulted from the resumption in compression of old normal faults in external zones interpreted by the notion of 'faults related folding'. This concept is related to an important movement on the ramps. For better understanding of this idea we have to study intracratonic chains from the example of Gafsa Basin.

The Gafsa Basin forms the southern border of Tunisian Atlas. It is delimited from Saharan platform by the southern Atlasic front, which is spread out from Agadir in Morocco to the folded structure of the chotts chains over 2000 kilometres.

The activity of this front was the object of several studies as a paleogeographic limit between two fields; one tectonized formed by Atlasic chains and the other stable defined by Saharan platform (Figure 1).

In Tunisia this front affected the southern Tunisian Atlas by the two faults of Gafsa and El Mich. The Gafsa basin is constituted with anticlines separated by tabular field. We notice that the major direction of these anticlines is E-W to NW-SE.

The genesis of structures in this area was interpreted by several authors, that Zargouni (1985) who considered us echelons folds that deep seated in craton structures. However, Outtani (1985) and Ahmadi (2006) proved that those folds are related to the emergence of major strike-slip fault or tear-fault affecting only the coverage, but will reactivate the inheritance structures (Figure 2).

The juxtaposition of the two largest chains in Gafsa Basin, that of Orbata and Bouhedma, form a tectonic corner named the 'Orbata-Bouhedma junction'

The aim of this contribution is to interpret different tectonics events affecting Cretaceous series in Orbata-Bouhedma junction and set up a model of their installation in order to prove the importance of reactivation in compression of old normal faults.

2. Methodology

This study is interested in determining the installation mode of the intracratonic chains in Gafsa Basin referring to the construction of balanced cross section. It was made by using several steps related to:

A stratigraphic study was carried out of different formation leveling in the sector. Such a thickness or facies variation are related to a synsedimentary tectonic activity

A fine cartography of the sector, demonstrates the different faults activity during tectonics phases, basing on development of geological cross section.

For this work we used the numerical software Rampe E.M. (Mercier, 1990, 1994), the modeling of geological structures is carried out by balancing cross section with always preserving ground data.

Several tests are done in order to approach the suitable model. The results obtained by modeling allow us to interpret; decollement level, the thickness crossed by the ramp and the displacement carried out during deformation.

The last stage is to interpret the results obtained by modeling and to compare them with the petroleum drilling in the studied zones.

3. Result

3.1 Cartographic data

Our geological map elaborated shows the outcropping of Cretaceous series cut out by faults in different directions. We distinguish faults of N110 to N120 direction, other of direction N150 to N160 and East-West direction (Figure 3).

The morphology of Orbata-Bouhedma junction is related to an important variation of direction from NW-SE in the western sector, to E-W in the east. This variation was interpreted in Gafsa Basin by Zargouni (1985) with an intervention of dextral strike-slip fault related to major faults with N120 E° direction, whereas Boukadi (1984) proposed the assumption of torsion around the vertical axes. Zouari (1990) considered the importance of the extensive structural heritage associated later to folding of structures with curved axes. Finally, Ibouh et al (1993) combined the activity of the dextral strike-slip faults with the overlapping of Fault in Jbal Bouhedma.

In order to have an interpretation of genesis of structures it is important to begin with studying the data observed in field presented in form of stratigraphics and structural data.

3.2 Stratigraphic data and synsedimentary activity

All formations outcropping in the sector are defined on the following stratigraphic columns (Figure 4).

The detailed studies of these formations show a significant variation of thickness and facies from one area to another.

Firstly the examination of dolomites of Meloussi formation shows slits, clogged later by calcites. These slits with NW-SE major direction resulted from an extensive tectonic activity with the same direction of lengthening axis than that of slits

The Bouhedma Formation, aged higher Hauterivien lower Barrémien, presents a great variation of facies. In Eastern termination of Jbal Orbata at the level of Jbal Taghrout, this formation is defined by sequences of argilloarenaceous and other argillodolomitic in addition to very fine sand and rare gypsum level. While approaching to Jbal Bouhedma, to the Eastern termination of the Jbal BouMiza, we distinguish predominance of argilloarenaceous silty sequences.

This formation presents at the level of Jbal Taghrout some figures of 'slumps' with intercalation of carbonated nodules indicating slope's instability. That confirms an extensive activity at the origin of the creation of a shallow and swing the northern side of Eastern termination of Orbata chain (Figure5).

The study of slickenside affecting the Barremo-Hauterivian series proved an extensive mode of deformation, with NW-SE direction of lengthening axis; it is a normal fault that permits the pinching out of series and creation of horst and grabens.

The Orbata Formation, for Aptian aged, corresponds to dolomitic cornices represents at the level of Jbal Timidwin in form of staircase shape. This structure is delimited by normal faults of NE-SW direction; thus indicating an extensive activity.

Thickness variation is also observed in other formation from one area to another. For example, going from Jbal At Tahir in the North-East sector to Jbal Sgoufta, the stratigraphic sequences given by the formation of Sidi Aïch, Orbata and Zebbag show a thickness reduction and even gap of Aleg and Abiod formations. This thickness reduction is related to the synsedimentary activity faults FS and FM.

In the area of Bou Blal the thickness of Aleg Formation can reach 500 metres, whereas in the area of Migli their total thickness does not exceed 10 metres. It is represented primarily by breaches of dissolution and conglomerates carbonated indicating significant tectonics synsedimentary during this period.

Lithostratigraphic correlation to level of Orbata-Bouhedma junction shows a thickness variation of certain formations and gap of others related to the tectonics activity of faults such as the Sgoufta Fault FS and that of El Mich FM (Figure 6).

This thinning of series was already proven by lithostratigraphic correlation carried out on both sides of faults quoted. Slickenside Data of FS (N160, 70NE) prove an extensive activity. The lengthening axis is NE-SW direction.

To North-East of our sector we notice a direct contact between carbonates of higher Zebbag formation with limestones dissociated and dismantled of Aleg formation. These limestones dissociated from dissolution of breaches observed in Khanguit elbhima area result from creeps of anhydrites which surmount limestone at the base of Aleg Formation. These breaches constitute an argument of bottom instability in the basin related to a tectonic activity during Turonian and Coniacian. Moreover, the Aleg Formation shows a pinching out of series that prove the activity of the FS fault and even total gap to the East of FM fault; it is an extensive activity (Figure 7)

These sedimentary and structural data confirms the extensive activity affecting Gafsa Basin during Early Cretaceous. It is an activity that confirmed by several authors (Zargouni, 1985). It continues to express during Late Cretaceous affecting the dolomitic cornices of Orbata Formation (Aptian age), Zebbag formation (Albian to Turonian age) and it continues even during Coniacian (Indicated by dissolution's breaches of Aleg Formation).

3.3 Structural data

The first cross section studied affects the east extremity of our sector for NW-SE direction. It shows an anticline structure cut out by synsedimentary faults (Fig 8).

This cross section determined by an anticline of N30 axis direction, the series have almost identical dip on two flank (about 45°), whereas the layers in the heart are rather rectified with an acute hinge. (Figure 9).

The heart of the anticline is affected by a fault of N30 direction; it permitted the swing of NW side and the rising of southern side. This activity explains the thickness reduction of series. More to SW this fault was already studied by Zouari et al. (1990) at the level of Jbal Zaïcha which confirmed their normal activity without excluding its reactivation.

The direction of anticline axis proves that the genesis of this structure is related to a shortening of NW-SE direction, it is the same direction of lengthening axis during Cretaceous.

The faults affecting Jbal ad Darin (N40 direction) confirms an extensive activity during lower Cretaceous. This activity continues to express even during deposits of Zebbag Formation (Upper Cretaceous). Faults will be taken again later by a compressive mode at the origin of their reactivation in sinisterly strike-slip-fault. This Compression is of shortening axis NNW-SSE direction; that is the direction of major shortening alpine on the scale of Tunisia. It is a shortening that also argued by sigmoid slits of direction N140 observed at the level of Jbal Bou Miza.

The second cross section is carried out in Jbal Sgoufta to NW and Jbal TazTigart to SE affecting the solid mass of the Jbal Bou Miza. It shows an anticline with heart formed by a tectonic thickening structure.

The normal activity of Sgoufta Fault assigning the series of Sidi Aïch to Zebbag Formation, presents a throw about 20 meters.

This cross-section was raised in a corner delimited on both sides by two faults of FS and FM. Respectively to the East and the west. These two faults prove an extensive activity during Cretaceous (marked by the beveling and even gap of series going from Bouhedma Formation until Abiod Formation), thereafter they will be reactivate by a compressive phase. It is the Atlasic compression of Tortonian age, at the origin of resumption of these two faults in dextral strike-slip-fault. The reactivation of this fault in dextral strike-slip-fault proves well that the general direction of shortening axis is NW-SE to submeridian.

This corner is delimited by the two faults FS and FM; their reactivation is at the origin of an important deformation expressed by subverticalisation of layers at the level of Jbal Sgoufta and tectonic thickening structure. (Figure 10).

The Sgoufta massive is cut out by secondary synsedimentary fault of direction N150 to N170. Among these faults we can distinguish those which are inverted affecting the series of middle and higher Zebbag Formation. Those faults have a weak width and born on the prolongation of the old normal faults.

More to the east, and along the fault of El Mich, we find Jbal atTaghli; it is delimited by a tectonic lens. The folds in this zone have major direction N60, lay out in sigmoid form and separated one from other by secondary order faults. The genesis of these folds is related to shortening during compressive phases associated to tangential activity.

From west to east we can distinguish four folds defined by three anticlines separated by faults, whereas the only synclinal is observed in the east limit. The direction of those folds and their sigmoid form confirms that their genesis is related to a shortening of NW-SE direction; it is the direction of alpine compression, aged upper Tortonian. It is the most important in favor of the genesis of folds.

The tightening is continued to express, allowing the overlapping of anticlines, from west to east. Thus giving birth to imbricate structure in form of 'duplex' (Figure 11)

The important quantity of deformation in this tectonic corner explains the gap of synclinals between three anticlines, already quoted, and thus allows interpreting the overlapping of imbricate structures in the shape of 'duplex'.

The deformation accentuated is also proved by the subverticalisation of the faults which delimit the folds, whereas towards the east a synclinal structure constitutes the zone of forelimb.

We can interpret that the stratigraphic and structural data show that Gafsa basin is subject to more than one tectonic phase. During early Cretaceous reigns an extensive phase, of NW-SE direction, proven by the beveling of the series of formations Meloussi, Bouhedma and even Boudinar. This phase is shown by the normal activity of faults, and continues to express even during late Cretaceous.

The resumption in compression during the alpine phase is carried out according to a shortening of NW-SE direction (it's the same direction of lengthening); what permeated the genesis of the great Atlasic structures (Jbal Orbata and Jbal BouHedma). This compression continues to occur until actual with submeridian direction of shortening allowing the reactivation of the old normal faults even in inverted fault.

To leave the structural chart of studied sector (Figure 12) we notice that the deformation increases on both sides of fault. While going from the west to the east sector and approaching to El Mich fault, the structural reliefs show an important rising with individualization of tectonic thickening structures (towards the south of the J. Sgoufta and at the level of Jbal Sha'bita and Jbal Abd Allah).

More to north east, on the level of the Jbal at Tahgli, the fault of El Mich confirms its important role in the genesis of imbricate structures. The secondary faults as being breakable disunite the folds leading to the overlapping of anticlines; they are the tears faults

We can interpret that the genesis of structures is related to the reactivation of old normal faults during different compressive phases, hence the importance of tectonic inheritance concept. Any interpretation of installation mode of structures must take into consideration the role of old faults in their genesis, which will be better explained in the next part.

4. Discussion and modelling

4.1 Discussion of results

Stratigraphic and structural data studied in Orbata-BouHedma junction proved the activity of several tectonics phases from Trias until actual.

Since the Trias, central-Southern Tunisia was subject to an extensive mode expressed by normal faults. The most important ones are those of Gafsa and El Mich, which are at the origin of individualization of half grabens and grabens, also described in the seismic profiles affecting all the basin of Gafsa. Bedir et al. (2000).

This activity continued to express during the deposit of the early Cretaceous series which is proved by the pinching out of the layers. The examination of the slickenside affecting Boudinar and Bouhedma Formation that shows again a normal fault generally with the tilting of the north compartment. The origin of the creation of a Shallow that is explains the structuring of different slope's figures.

The extensive phase continues to express during late Cretaceous; indeed a thickness variation was already observed in Orbata and Zebbag Formation, which confirms that this extensive activity persists at the base of late Cretaceous.

More to Jbal At Tahir we notice an angular discordance of Abiod formation series with dolomites of Zebbag formation accompanied by an important pinching out of Aleg formation series (described by breccia's dissolution).

It is an extensive phase during the deposit of Aleg Formation, which presents the continuity of extensive activity already quoted, taken again thereafter by a companso-maastrichtian compression. This late compression is of local order; it is of E-W direction, also described in Gafsa Basin. In our sector it is related to the blockage of the two massive of Orbata and BouHedma at the level of El Mich Fault

The western extremity of the sector shows an anticline with NE-SW direction, it is the Eastern termination of the Orbata chain formed by two symmetrical flanks. More approaching to Sgoufta and El Mich Faults, we notice an increase of deformation with individualization of tectonic thickening structure in the Jbal BouMiza termination. This structure is also observed in the southern sector in Jbal Sha'bita and Jbal Abd Allah. These two anticlines are wedged and delimited by faults without syncline. The compression associated to the reactivation of faults separated by anticline was permitted the sinking of synclines and outcropping only anticlines wedged at the level of faults.

Moreover, this structure is observed to Jbal atTaghli, it is imbricates anticlines delimited by faults without synclines. This structure resulted from an important deformation which affected this tectonic corner. It is related to reactivation of El Mich Fault during different phases of compression from Neogene until actual.

In fact, the genesis of these folds, of major direction N60, result from the alpine compression of shortening direction NW-SE. these folds are cut out by the ramifications of El Mich Fault.

More the compression increases (Villafranchian phase) than the rejuvenation of the faults is important, leading to the tilting of the synclines and the overlapping of the anticlines.

The corner of Jbal atTaghli presented in the form of tectonic lens delimited by two subparallel faults. Their combination activities were at the origin of wedging of the anticlines. It is the notion of tear fault.

The structural study of Orbata-BouHedma junction confirms some former works interested to close localities (Ahmadi 2006; Outtani1995). Indeed the geneses of the folds are related to tectonic inheritance and rejuvenation of old normal faults during different compressive phases that prove the concept of "fault related folding".

4.2 Modeling

In This part of contribution we present an interpretation by the modeling of stratigraphic and structural data related to different phases of deformations. This part of work was carried out by using numerical model developed by the software Ramps E.M. 1995.

This work started by interpreting the geometry of folds. Then balanced the cross-section obtained on the field, according to the suitable model. The general structural frame leads us based on the concept of ramps and balanced cross section.

The resumption in compression of these structures allows an inversion tectonic giving rise to folds, which are born on these old normal faults. During the genesis of these folds «fault related folding" they express on ramps. We distinguish particularly three types of "faults related fold" which are "fault bend fold", "fault propagation fold" and "chester". The difference between these models is related to the geometry of each one:

The most important factor to interpret the suitable model is the geometry of fold hinge. The cross section already elaborated on ground shows folds with hinge acute and subvertical layers (as watch Figure 9). This geometry is related particularly to the importance of fold's growth following an accommodating of slip on the spot. This geometry remembers the model of 'fault propagation fold'.

This model is also proved to NW termination of Jbal Bou Miza exactly in the north of wad Ed Dhribin, where the growth of fold was carried in a superficial context at the origin of raising structural relief. The phenomenon of erosion was activated is presented in conglomeratic deposits form at the base of structure in the frontal synclinal trough (Figure 13).

In this frontal trough bend we show a rounded pace very accentuated which indicated a less significant radius of curvature. It is explained by supplementary shearing related to recent compressive context superficial.

After determining the mode of deformation we propose to model the geological cross section already elaborated and then balanced by using numerical software called Rampe EM (Mercier, 1990-1995). The results obtained by this model allow us to interpret the altitude of lower dish, dip of downstream side (fore limb), dip of upstream side (back limb), crossed thickness and displacement (Figure 14).

After several tests of modeling we deduce that the decollement level is within triassic series, the ramps is blocked with the last carbonated level from Jurassic and their dip is about 38° which explains the symmetrical plunging of the layers in the two sides of the anticline.

The adapted displacement is about 1.2 km related to a shortening of direction NW-SE from northern side. These parameters are in relation to the progression of the deformation at the origin of the modification of the mode to thrust

propagation with shearing of the reversed limb. They allow important rising of the structural reliefs that will be eroded and deposited in the form of dismantlement products at the base of structure.

We should notice that this model is checked only with an important thickness of the Jurassic series which is 1000 meters. So this thickness was proved by the petroleum drilling carried out within the Gafsa basin. Indeed, towards the west in the area of Metlaoui a petroleum drilling GN presents a series thickness of Jurassic that do not exceed 500 meters, whereas while approaching to our sector other petroleum drilling KR and SO shows thickness which exceeds even 1500 meters.

This variation of series thickness of Jurassic is explained by the activity of Gafsa fault during Jurassic period (Figure 15).

The second cross section to be modeled is delimited by the two faults of Sgoufta and El Mich. It is also shows an anticline structure with a geometry which confirms the model of "Fault propagation fold" (acute hinge with rectified layers).

The balancing of cross section, by using the same software Rampe EM (Mercier, 1990, 1995), permeated us to adopt the model proposed on Figure 16.

This model shows again a decollement level in the Triassic series with a ramp which reaches the dolomitic levels of the base of Bouhedma Formation. We should state that in this model the displacement is more important than that observed in the preceding cross-section which confirms more deformation. This deformation is proved by the structural geometry forms of tectonic thickening.

The second cross section is delimited on both sides by the two faults FS and FM. So the rejuvenation in compression during the alpine phase was at the origin of an important blocking in the edge of these faults which explain even the subverticalization of layers at the level of Jbal Sgoufta.

The maximum of deformation is proven in the proposed model by an important displacement explained by the rising of structural reliefs. The maximum of deformation is also observed in Jbal atTaghli which show imbricates folds formed by overlapping anticlines (Figure 17).

In order to interpret the kinematics of Jbal atTaghli we notice that it is presented in the form of duplex structure with an important role of back-thrust activity. To the west of cross section, the migration of two anticlines is in the same direction of shortening, from NW to SE. However, the third fold presents a dipping of its axis in the opposite direction. This back-thrust is branched in a shallow decollement at a higher level. The genesis of structures is related to antithetic activity of fault in edge of major fault (fault El Mich).

5. Conclusion

The Orbata-BouHedma junction is subject to more than one tectonic phase which continues to express until actual. The syndimentary tectonics analysis confirms that this sector is subject to an extensive activity from the lower Cretaceous. This distension that begins from Trias is responsible for the opening of the Atlantic Ocean and individualization of the great normal faults such as El Mich Fault. Thereafter an alpine Cenozoic compression permeated individualization of most chains in all Gafsa Basin. Another compressive activity other than alpine phase observed in our sector which are local and related to the combined activity of faults (compano-maastrichtian compression).

The Gafsa Basin is presented as a typical example of genesis of intracratonic chain. The developments of these chains are related to the resumption in compression of the old normal faults, according to the fault related folding mode. To understand the mode of installation of these structures we propose a geometrical modeling of 'forwards' which is based on the balancing of the geological Cross section. This method allows us to conserve the rough geological data of ground and interpret their geometry.

The rejuvenation in compression with the same direction axis of lengthening during alpine phase is at the origin of the development of the structures in old normal faults, proving the concept of 'fault related folding'. The proposed model of 'fault propagation fold' confirms the ground data already elaborated. It was checked by the petroleum drilling, soon a geophysical study on the same area can confirm the results obtained and verified the role of the tectonic heritage in the genesis of structures, which continues to express until actual.

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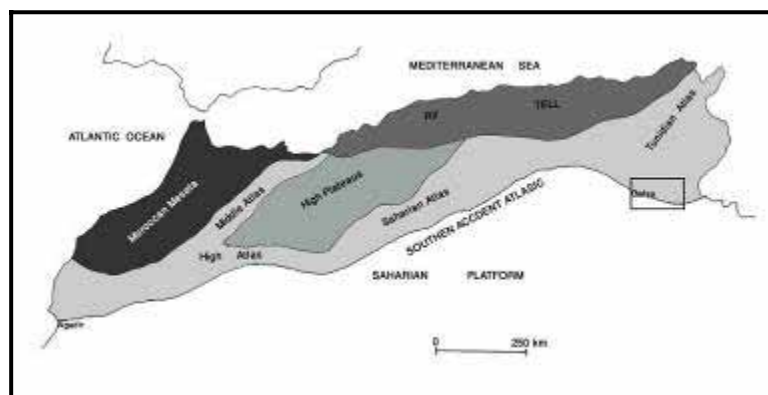


Figure 1. Presentation of different structures in the Atlasic chains of North African

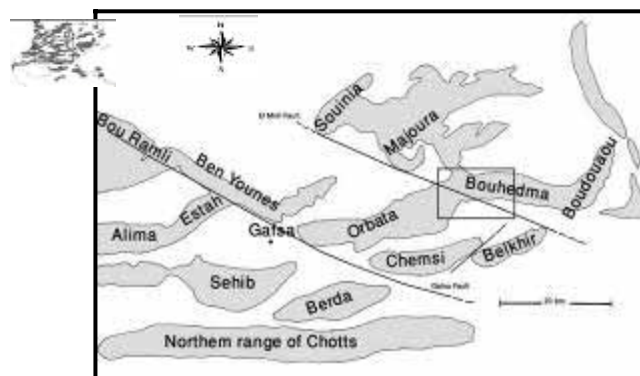


Figure 2. Localization Chart of studied sector in Gafsa Basin

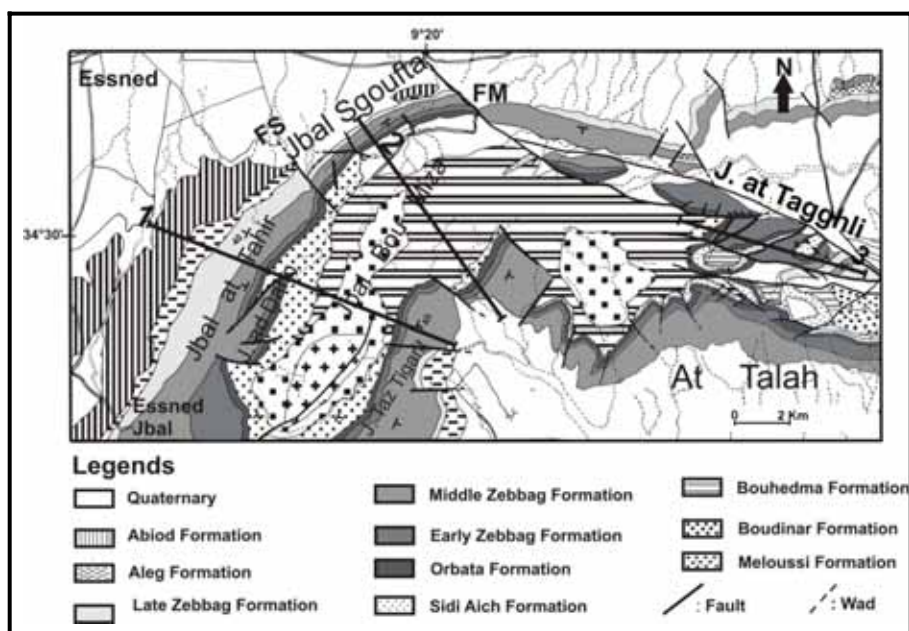


Figure 3. Geological map of studied sector showing the activity of different major faults

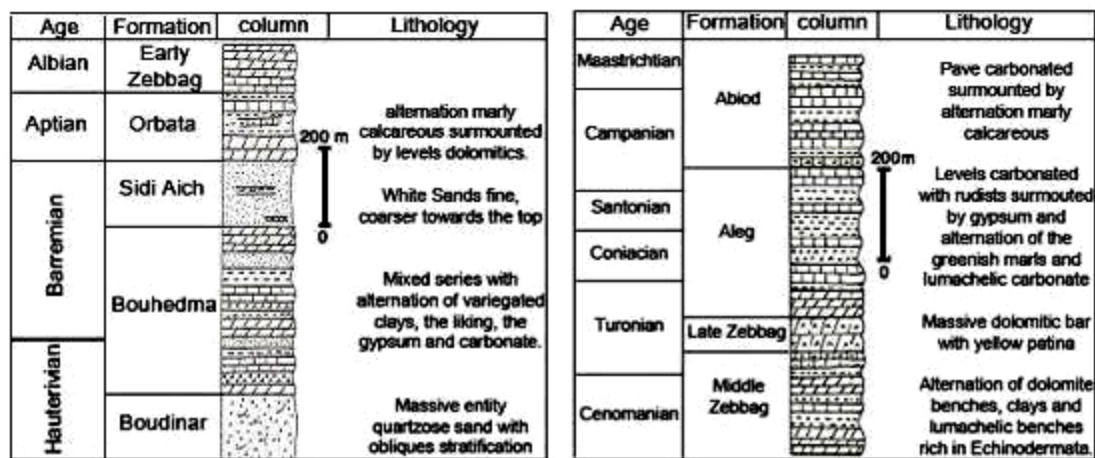


Figure 4. Lithostratigraphic column describing different formations studied in the sector: series of the early Cretaceous are to the right and those of late Cretaceous are to the left.

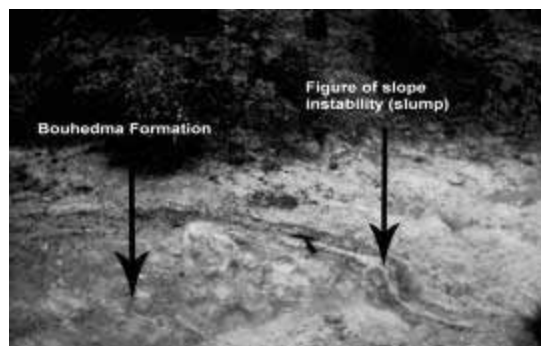


Figure 5. Slumps Figures affecting Bouhedma formation related to slope instability that indicate an extensive activity during early Cretaceous.

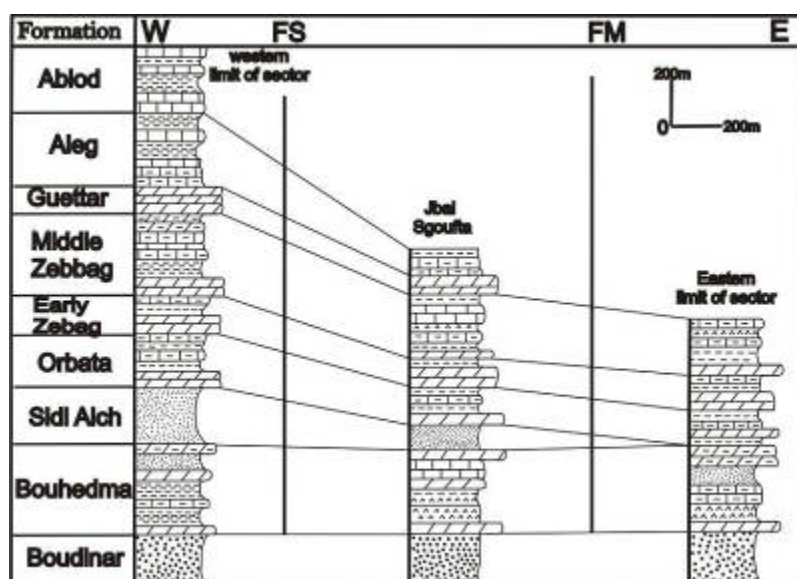


Figure 6. Lithostratigraphic Correlation of Cretaceous series on both sides of Sgoufta Fault FS and El Mich fault FM

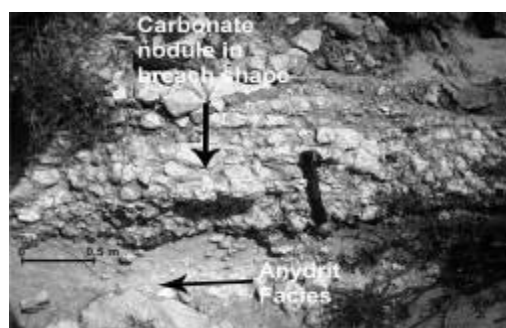


Figure 7. Dissolution's breccia of Aleg formation confirms the extensive activity during Coniacien age

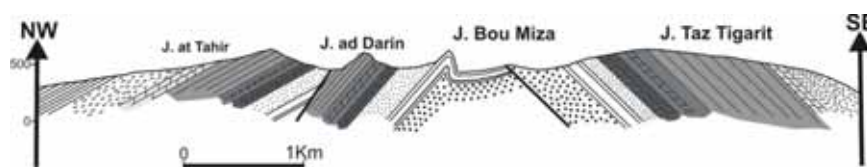


Figure 8. Cross section elaborated at the Eastern termination of Orbata mass showing a monocline structure affected by sinistral strike-slip fault (same legends of figures 3)

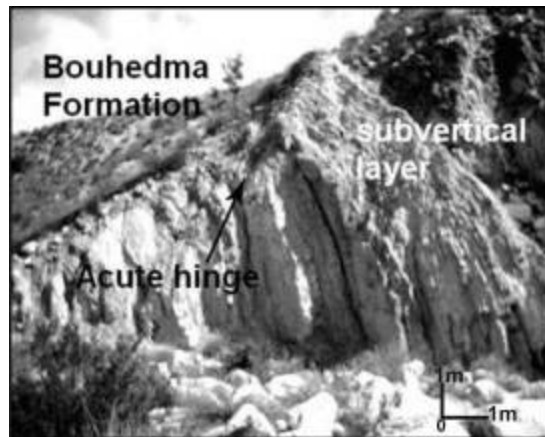


Figure 9. Geometry of fold presented by acute hinge and subvertical layer



Figure 10. Geological cross section of Jbal Sgoufta proving an important tectonic deformation between the two faults of FS and FM

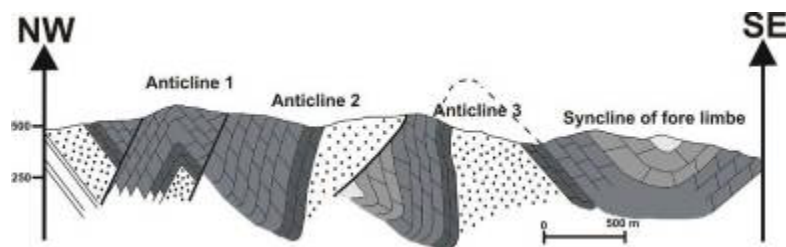


Figure 11. Cross section at the level of Jbal atTaghli showing the overlapping of the four folds separated by faults offered the form of "duplex" (same legends of figures 3)

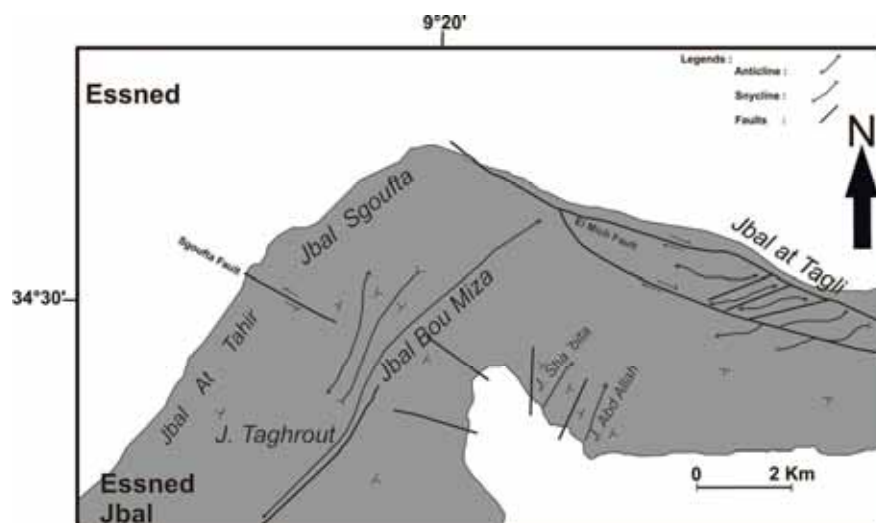


Figure 12. Structural chart of studied sector proving the important role of faults in the increase of deformation

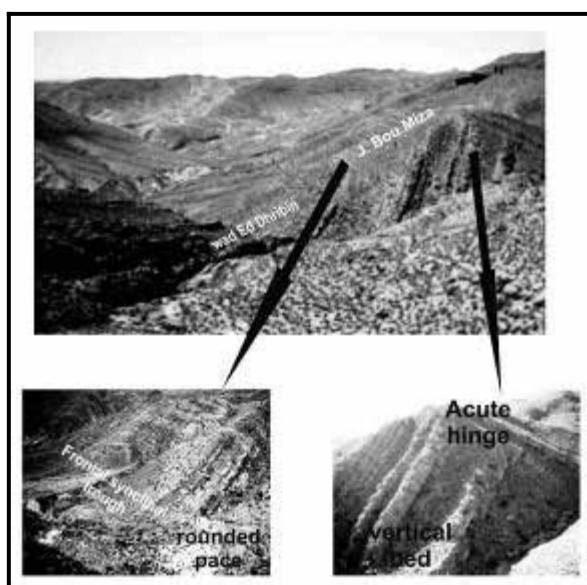


Figure 13. Morphology of the folds in form of acute hinges shape and rounded pace of the frontal syncline trough

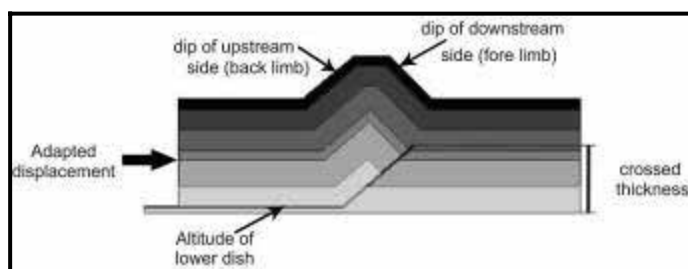


Figure 14. Different parameters interpreted in the application of model fault related fold

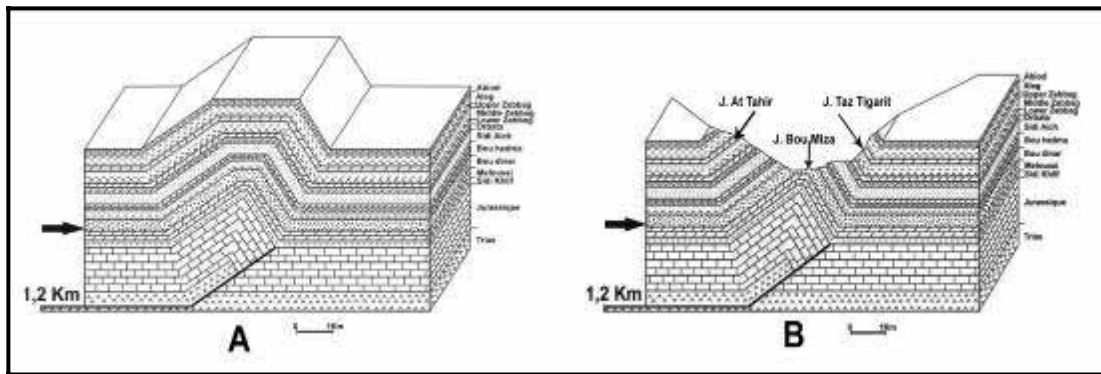


Figure 15. A: Result of modeling of cross section 1 in mode of fault propagation fold; B: Model of cross section 1 resulted after erosion.

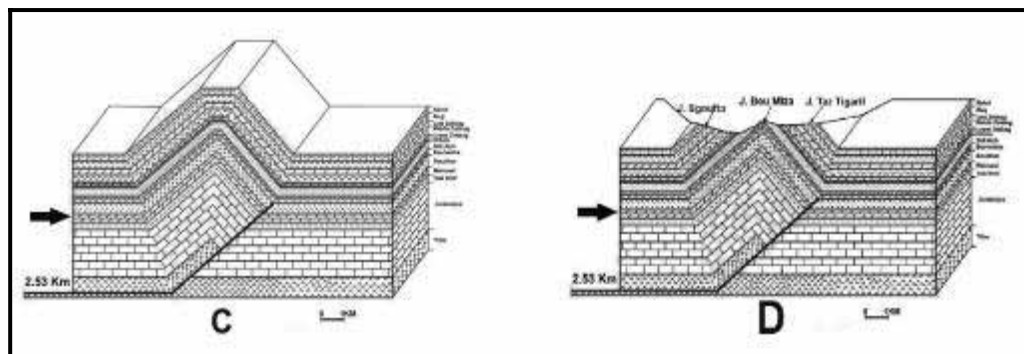


Figure 16. C: Result of modeling of cross section 2 in mode of fault propagation fold; D: model of cross-section 2 affected by erosion.

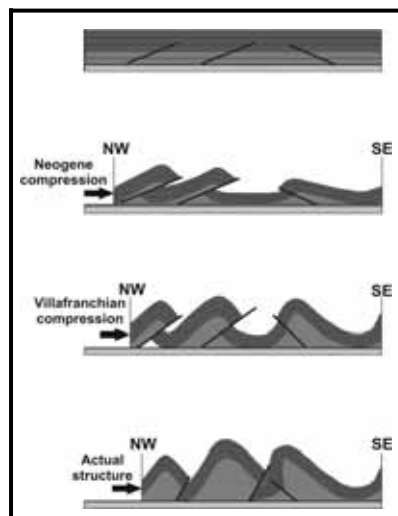


Figure 17. Kinematic and genesis of Jbal atTaghli in form of duplex structures resulted to reactivation of El Mich fault

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