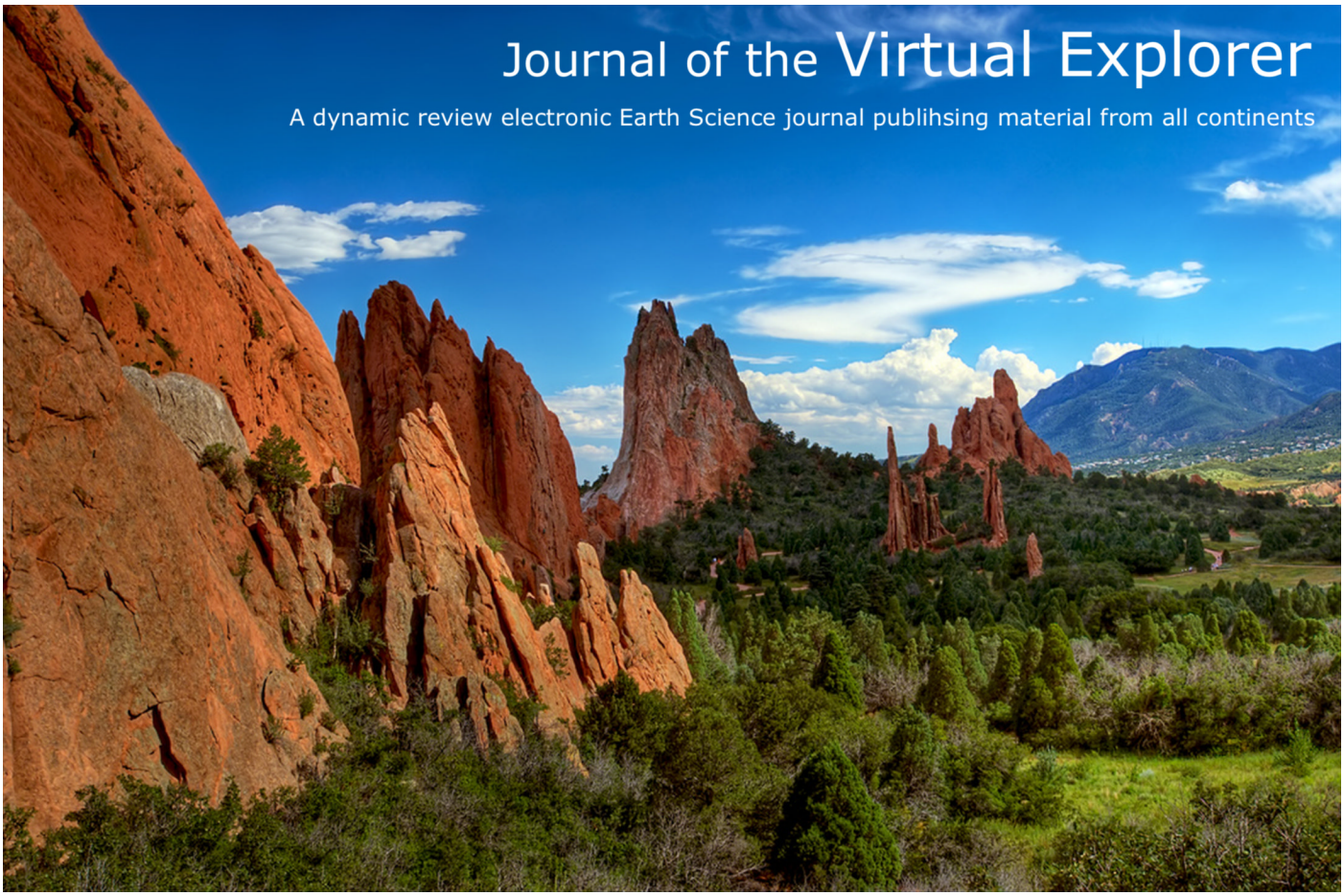

Geographic Information System for Natural Resource Management of Pakistan

Hammad Hassan Tariq, Zia Ul Hasan Shah, Ghulam Mujtaba, Shahina Tariq, Mohammad Zafar, Umar Zubair

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Abstract: The use of GIS in the natural resource industry is widely recognized due to the linking of spatial information with attribute data in the underlying database. A comprehensive and interactive GIS was developed for the natural resource management of Pakistan, which includes Seismo-tectonics along with associated geological structures and minerals, and upstream petroleum activities. Demographic, hyrdogeological and administrative information are also the integral part of the GIS. This GIS database will help the geoscientists to analyze the information like the areas that have suffered intensely by the tectonic activities, analyzing tectonic activities and resulting structures, and to highlight the areas of higher risk where probability of earthquake occurrences is more, etc. It also relates tectonic history with minerals that could help the future mineral exploration in the area. Furthermore, different scenarios can be analyzed which helps in the decision making and thus strengthening the nation, with appropriate planning.

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Introduction

Since time immemorial, it has been a constant endeavor of human being to pursue various aspects of life with ease. In the present era of high-end computing, this endeavor of simplifying things is well achieved by an effective tool like Geographical Information System (GIS). Unlike the conventional procedure of simultaneous handling of various maps such as village cloth maps, engineering drawings and Layout plans etc., which are of different scale, GIS helps to prepare the maps and peruse the maps of multiple types at the same instance. The concept of layer mechanism and subsequent superimposition one above the other is used so as to store both non-spatial and spatial data in different thematic layers. This enhances data accessibility, and also helps simultaneous operation of perusal and analytical assessment of the information to be used prior to any land acquisition process.

GIS is a computer-based software that links geographic information (where things are) with descriptive information (what things are). Five basic components of a GIS include the computer system (hardware and operating system), the software, spatial and attribute data management, analysis procedures, and the people to operate the GIS. A GIS must always exhibits six functionalities that include Data Capture, Storage, Management, Retrieval, Analysis and Display (Clarke, 2001).

All GIS software has been designed to handle spatial data (also referred to as geographical or navigational data). Spatial data are characterized by information about position, connections with other features and details of non-spatial characteristics (Burrough, 1986). Inappropriate referencing system may restrict future use of the GIS (Openshaw, 1990). GIS supports both raster and vector data models for the representation of real-world features (Dale and McLaughlin, 1988 and Peuquet, 1990).

GIS for Natural Resource Management

The use of GIS is widely recognized worldwide due to the linking of spatial information with attribute data in the underlying database. GIS can be used in almost all fields of life including mining and earth sciences, archaeology, agriculture, banking, defense and intelligence, engineering surveying, federal government, Fire/EMS/disaster/homeland security, forestry, health and human services, insurance, education, landscape architecture, law enforcement and criminal justice, libraries and museums, location services, state and local government, telecommunication, transportation, water and wastewater, geology and hydrogeology, natural resource management, population forecasting, facilities management, etc.

The application of GIS in natural resource management organizations has become commonplace during the last decade. Part of the reason for this widespread use is due to the analytical efficiencies GIS provides, but it is also due to the continued technological advances in computer hardware and software. Computer prices, in fact, continue to decrease while processing power and storage efficiency grow. A wide variety of GIS software programs have also emerged, and the trend in GIS software program design has been to make the programs more user-friendly. As most of the natural resource issues have a significant spatial component and GIS can be used extensively to visualize, analyze, and model natural resource data for management and problem solving.

A comprehensive and interactive GIS was developed for the natural resource management of Pakistan using ESRI ArcView© GIS and ESRI ArcInfo©. ESRI Arcview© is a powerful, easy-to-use desktop mapping software tool that provides the power to visualize, explore, query and analyze data spatially. In the first phase, infrastructure of Pakistan including provinces, districts of Pakistan and Azad Jammu and Kashmir, major rivers, offshore boundary of Pakistan etc. have been included. Furthermore, major geological structures, mineral deposits and mines, Seismo-tectonics along with associated geological structures and minerals, Seismo-tectonics of Pakistan including the areas that have suffered great damage from the earthquakes in past, all major earthquake epicenters and oil and gas wells drilled so far along with other upstream petroleum activities were included. The summary of all these data has been mentioned in Table 1 and 2. (Figure 1) shows the overall methodology adopted for building the GIS for natural resources of Pakistan.

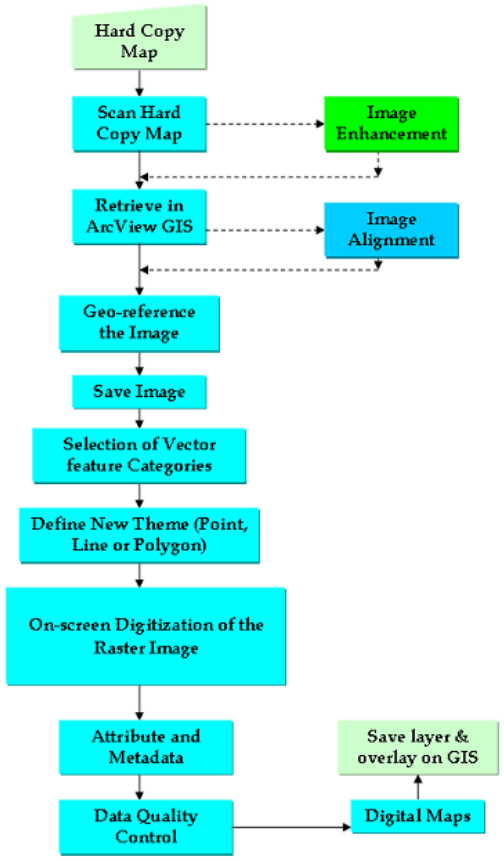
Table 1. Table summarizing the details of natural resource themes

Sr. No.	Theme Name	Feature Type	Feature Description	Attribute Data	Source
1.	Upstream Petroleum Activities	Point	Oil and gas wells along with other upstream petroleum activities	SegID, Well name, operating company, and age of objective formation, rig description, well type, concession name, SPUD date, drilled depth, target depth and present operation	Hard copy map of Upstream Petroleum Activities, September 2004 published by LMK Resources in collaboration with DGPC and PPEPCA.
2.	Earthquake Epicenters	Point	Epicenters of major earthquakes. This theme contains one thousand and twenty two earth-	SegID, Magnitude of the earthquake and its depth in km.	Preliminary Seismotectonic Map of Pakistan, issued by the Geological Survey of Pakistan in 1979.

Table 2. Table summarizing the details of infrastructure themes.

Sr. No.	Theme Name	Feature Type	Feature Description	Attribute Data	Source
1.	Boundary of Pakistan	Line	Onshore and offshore boundary of Pakistan	SegID, Segment Name	Map of Area and Population of Pakistan (district and provincewise) in year 2003, by Survey of Pakistan.
2.	Provinces of Pakistan	Polygon	Provinces of Pakistan	SegID, Province name, Total area, Population and the number of districts in the province	Map of Area and Population of Pakistan (district and provincewise), in year 2003, by Survey of Pakistan.
3.	Districts of Pakistan	Polygon	Districts of Pakistan	SegID, District name, Area in square kilometer, Popula-	Map of Area and Population of Paki- stan (district

Figure 1. Overall methodology



Workflow adopted for the development of GIS for natural resource management of Pakistan.

Data Analysis and Manipulation

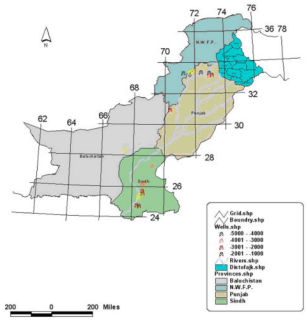
Two general types of queries, spatial and aspatial, can be performed with GIS. Aspatial queries are questions about the attrib¬utes of features like how much metallic minerals are present at any specific location whereas, on the other hand, estimation of metallic minerals in any particular district is a spatial query. The location of the minerals will be reported and could be presented in the map form. Many queries can be applied to the data but few exemplary queries along with their results have been summarized in Table 3.

Table 3: Selected exemplary queries along with their results in the form of maps.

Table 3. Selected exemplary queries along with their results in the form of maps

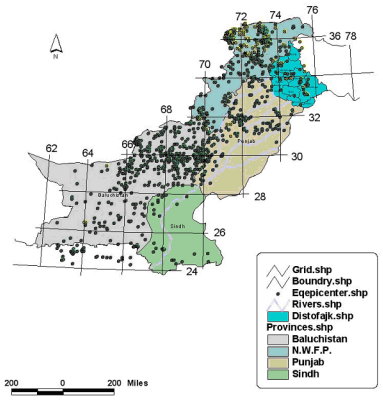
Sr. No.	Query	SQL Query	Result
1.	Show all OGDCL oil and gas wells drilled in 2004 with target depth less than 3300 ft.	([Target_dep] < 3300) and ([Spud_dt] = 2004) and ([Operator] = "OGDCL")	Result of this query has been displayed in Figure 2
2.	Show all earthquakes with magnitude greater than or equal to 5 having epicenter at depth greater than or equal to 100 km.	([Mag.] >= 5) and ([Dep_km] >= 100)	Result of this query has been displayed in Figure 3.

Figure 2. Result of query No. 01



Result of query No. 01 showing all oil and gas wells belonging to OGDCL having their target depth less than 3300 ft.

Figure 3. Result of query No. 02



Result of query No. 02 showing past major earthquakes with magnitude greater than or equal to 5 having their epicenter at depth greater than or equal to 100 km.

Interpreting GIS

One of the main purposes of using GIS is to generate different types of maps depending on the queries and analysis applied on the database. Arcview GIS refer it to layouts. Following few sample layouts along with their brief description/interpretation have been included in this paper to demonstrate the analytical capabilities of an integrated GIS developed for natural resource management of Pakistan.

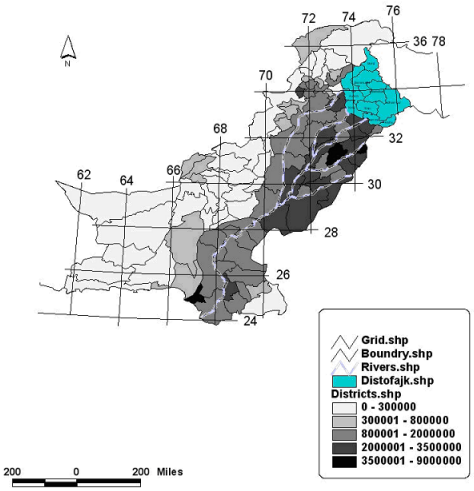
1. Population density of different districts of Pakistan

The GIS lets the users to make quick and reliable analysis based on its attribute data. (Figure 4) shows districts of Pakistan, represented with different color shades depending upon the population density. Higher population is depicted by darker colors and vice versa. GIS analysis concluded that most of the population has been surrounded around different rivers and stream. With the exception of some areas, which are around the rivers and are not yet densely populated due to some reasons like remote areas, unavailability of roads and basic necessities etc. will become densely populated with passage of time according to the growth trend of population. The main purpose of this type of analysis is the better planning for future, which may include development of roads, railway tracks, housing schemes, drainage channels, drinking water availability and many other such things, which requires to be done before time. Another use of GIS includes the proper resource management for a department whose job is to divide the resources among the districts according to their population and quota. This requires statistical analysis for making decisions, which will lead that department in the right direction. This planning for the future can greatly increases such companies profit ratio.

2. Major minerals of Pakistan

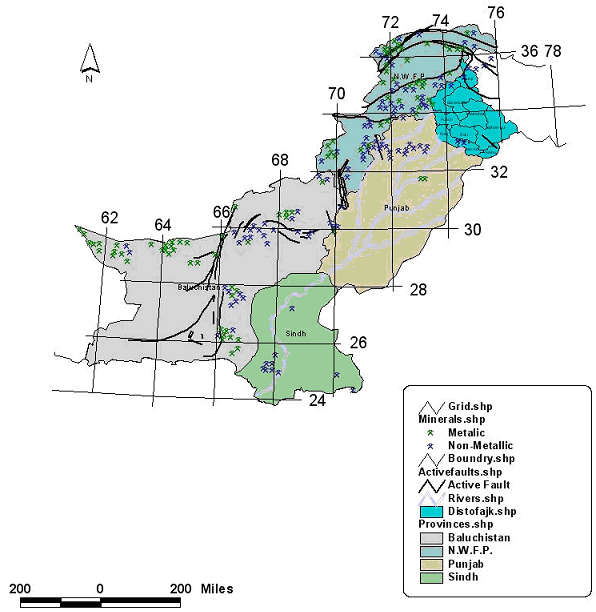
(Figure 5) shows different metallic and non-metallic minerals of Pakistan associated with different active fault boundaries. All this data have been compiled from Kazmi and Jan (1997). This type of analysis helps the exploration companies to select prospective sites for the possible mineral exploration survey, to understand the mineral occurrence with respect to its tectonics and structural associations.

Figure 4. Population density



Population density of different districts of Pakistan.

Figure 5. Metallic and non-metallic minerals



Map showing different metallic and non-metallic minerals of Pakistan associated with different active fault boundaries.

3. Oil & Gas Wells and Upstream Petroleum Activities

Figure 6 categorized the oil and gas wells drilled in 2004 on the basis of different exploration companies. Major advantage of this layout is to facilitate the foreign companies who are also interested in hydrocarbons exploration in Pakistan. That company, with the help of a GIS, can easily find about the current activities of exploration at a glance and about the companies that are more involved in exploration in that particular area. (Figure 7) shows different oil and gas wells drilled in 2004 with different target depth. This type of quick analysis revealed the trend of increasing target depth in the northern part of country and shallow target depths in the southern part of the country.

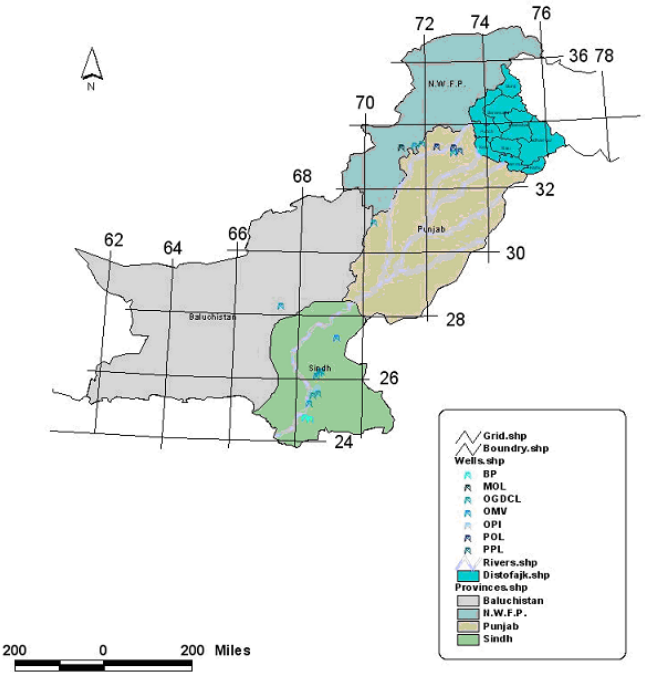
4. Major Earthquake Epicenters of Pakistan

(Figure 8) represents moderate-to-major earthquake epicentres of Pakistan and associated areas that have been suffered intensely. This layout will be especially beneficial for engineers, geoscientist, town planners, planning departments, and rescue and relief teams etc. This type of analysis will help the engineers to construct structures like high-rise buildings, dams, bridges etc. according to the prevailing building codes. On the other hand it will also help a lot to minimize the human casualties and property losses.

5. Geological Structures of Pakistan

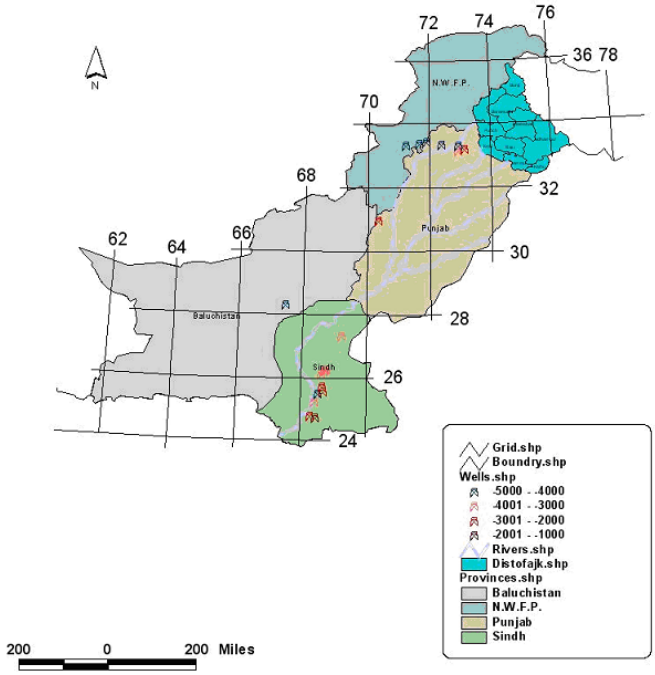
(Figure 9) shows the distribution of major geological structures in provinces of Pakistan with highlighted active fault boundaries. This will inturn help to explore the minerals associated with different geological structures and hydrocarbon exploration. Furthermore, it will also help to plan better for new water reservoirs, bridges, high-rise buildings, and other mega structures etc.

Figure 6. Oil and gas wells drilled in 2004



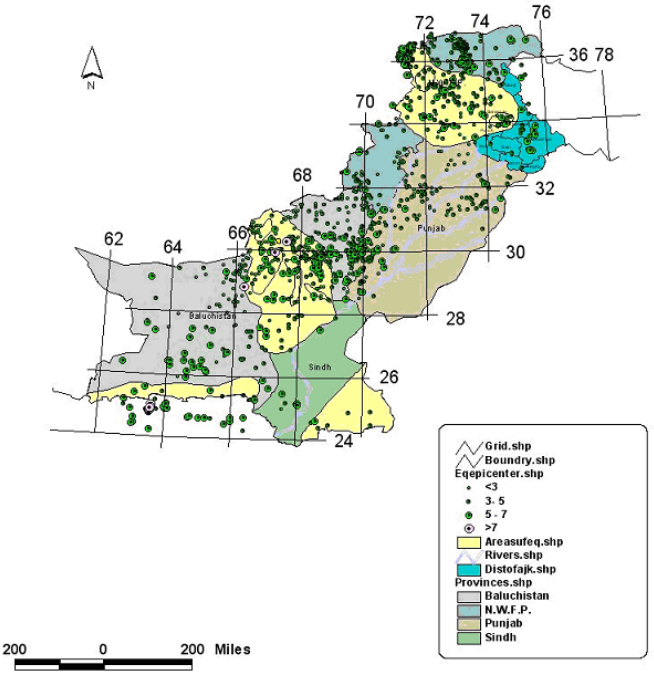
Map showing oil and gas wells drilled in 2004 on the basis of operating company as mentioned in the legend of map.

Figure 7. Oil and gas wells with different target depths



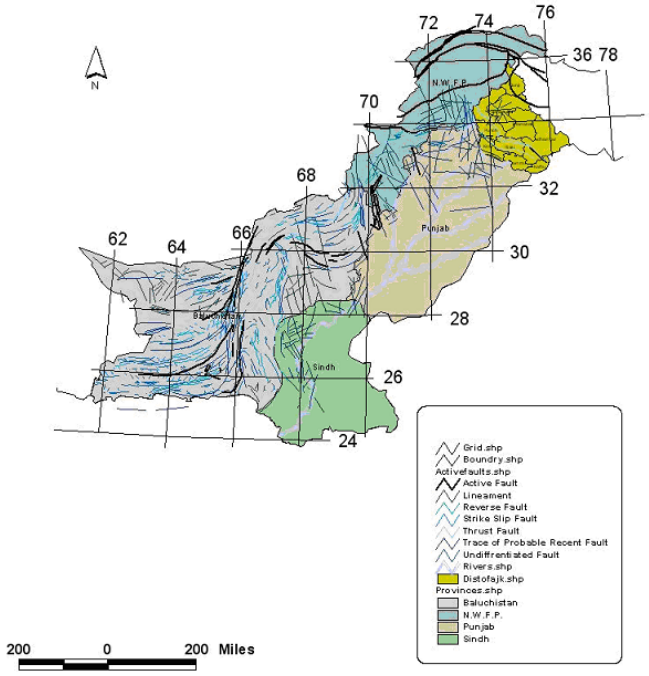
Map showing different oil and gas wells drilled in 2004 with different target depths as mentioned in the legend of map.

Figure 8. Earthquake epicenters



Map showing moderate-to-major earthquake epicenters and intensely suffered areas of Pakistan.

Figure 9. Active fault boundaries



Distribution of major geological structures in provinces of Pakistan with highlighted active fault boundaries.

Conclusions

Geographical Information System has become a widely accepted tool in all fields of life and particularly in natural resource management which inturn helps in monitoring and managing earth resources accurately and efficiently. A comprehensive and interactive GIS developed for the natural resource management of Pakistan will help the geoscientists to analyze the information like the areas that have suffered intensely by the tectonic activities, analyzing tectonic activities and resulting structures, and to highlight the areas of higher risk where probability of earthquake occurrences is more, etc. It also relates tectonic history with minerals that could help the future mineral exploration in the area. Furthermore, different scenarios can be analyzed which helps in better natural resource management, making timely decisions, and thus strengthening the nation.

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