The Jordanian Mineral Resources Geographical Information System: A First Step towards a Computerized Exploration of the Jordanian Mineral

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Abstract

The demands for better management of mineral resources require management of spatial information. Geographic Information Systems (GIS) can be defined as a complete computerized system designed to assist the gather, handling, modeling and presenting of spatially-based data for resolve, plan and manage sophisticated problems [20]. Getting the bottom of mineral resources presumed a great deal of importance in many developing countries such as Jordan (It is a country in the Middle East). Jordan is bestowed with ample mineral resources that have contributed massively to the natural resources with associated socio-economic advantages. This paper introduces a functional methodology to build a geo-referenced mineral wealth system called ("The Jordanian Mineral Resources Geographical Information System (JMR-GIS)"). With JMR-GIS, different classes of mineral wealth information can be gathered and merged to assist typical users to graphically represent novel relationships in GIS output digital maps. In general, GIS is utilized in several sectors in many countries, but such systems that manage the mineral wealth in Jordan are rare. So, the contribution of the methodology in this paper will be the first step to computerize mining of the Jordanian mineral resources.

Keywords: GIS, mineral resources, ArcGIS Desktop, and digital map.

1. Introduction

A GIS can be described as "A computer system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data related to positions on the Earth's surface. Typically, GIS is used for handling maps of one kind or another. These might be represented as several different layers where each layer holds data about a particular kind of feature.

Each feature is connected to its position onto the graphical image of the digital map" [26]. After over several decades of development, GIS have been utilized to avail important roles in several sectors, such as management of mineral resources. The eventual purpose of GIS is to make evaluations or predictions with different particular data integration models to embody spatial and attribute data from mineral resources to provide support for decision-maker in many sectors [18]. The GIS implementation is able to incorporate different formats of data; and in many areas, these data can be used for the analysis purposes [9]. The geographical data which is stored in GIS depicts spatial objects from the real world such as their attributes, position, and their scope of relationships with other spatial objects [2]. GIS can offer many benefits, capabilities and functions that help in various endeavors.

GIS can be used for mineral resource management such as how to find favorable areas for oil exploration in a specific region [22]. Thus, GIS is becoming less expensive and more reliable than ever before. These land marks extended executions of GIS for long-range studies of huge projects. Moreover, GIS can play a main role when used along with various applications in the developing countries such as a good administration of mineral resources. GIS may also enhance the function of mineral resources especially in the process of continuous development [22]. It also will bring an ideal tool to support advertising and managing possible mineral of a country. The stored information into a database about certain mineral occurrence could be queried and viewed spatially by the GIS. This makes the mineral location is able to be exposed in the course of additional information. Setting is

of the GIS properly makes plain activities to be automated and improves the system serviceability at the same time [17]. This paper is going to describe and develop such GIS systems by one of the GIS software packages which is ArcGIS.

This paper describes the GIS application in management of mineral resources for specific mineral potential mapping within Jordan. The developed GIS can be customized to assist the users of such applications. The development of GIS is draw from the data and experience given from the people developing GIS who are citizens of the country. As in[10] this work has shown that the application of a GIS to efficiently display, analyze and model complex spatial that enables the user to develop and test many more suppositions regarding the significance of mineral resource investigations than would be possible using manual or traditional techniques alone. The GIS of Mineral Resources and its associated spatial databases built for Jordan offers accessible digital data sets for the users and precious assistance for future planning.

The rest of the paper is organized as follows. Section 2 explains the GIS and its relationship with the management of mineral resources. Sections: 3, 4, and 5, introduce the developed system and its developing environment. Section 6 describes how the developed system does work. Finally, I conclude the paper in Section 7.

2. GIS and Management of Mineral Resources

Spatial Applications occur in major sectors of industry, business and government. These sectors include: GIS, remote sensing, medical physics, resource allocation and planning, environmental modeling. Normal statistics and geographic site can be combined by GIS tools in order to bring about clear, meaningful and fascinating digital maps that could be used to development needs [27].

GIS is considered as a significant decision-making technique for administering mineral wealth. GIS implementation is utilized to categorize the related problems with different issues such as: the analysis, storage, processing of deep seated information [21]. It is also used in integrating the forms of non-spatial and spatial information. The processing of such information is helpful in problem solving for the continuous handling of the mineral wealth [13]. Unlike the paper-based map (i.e. traditional map), the digital map in GIS represents the information by several layers (Environmental Systems Research Institute (ESRI), 2003). Moreover, GIS can interpret and manage data about spatial and mineral resources [21]. GIS as tools involve several tasks save, manipulate, and interpret spatial data. In order to do these tasks special devices should

be used such as: global positioning system or receivers (to measure and detect the geographic location); and aerial photos or satellite remote sensing (to supply land cover, frequent land use, and etc.) [5].

The alteration in social regulations, technological and economic impacts are playing the role as an interface between the public and the mineral sector government, which will lead to altering the requirements for knowledge and information according to the proper management of mineral wealth [16]. Last decade, there has been a significant change in the way of collecting mineral resources information, analyzed and even presented. Collection of data has been speeded up by using advanced scanning and digitizing. GIS and incorporated database technologies speed up the analysis of data, which may then be delivered quickly in table or map form to worldwide users through internet tools [16].

The main explicit implementation of GIS in Jordan as one of the developing counties is instrumental mapping, where experts interact with local people to bring about location-based inventories of mineral wealth, recognized troubles, and the rights of land use. These inventories got into an advisory operation targeted at constructing consent on more potential and equitable configurations of wealth management [21].

As being known by Nijkamp and Fischer [8], the significant capability of a GIS is the capacity to manipulate huge multilayered, heterogeneous databases and to execute location based queries and find the characteristics of a several spatial objects in an active manner. Thus, a GIS allows users to imagine data viewed as several layers. Stereotyped information about one certain class of real world elements such as town or road which may also considered as overlays and it can be described by layer. Diverse layers may be imposed extensively and a proper planning instrument may be developed quickly to relate too many issues that are expected to be very varied but they are spatially connected and linked [19].

GIS is a significant tool to analyze and forecast the future variations. Its strength come from its ability to do spatial and statistical information analyses that extracted from the geographical positions correlations. By these features, they achieve wealth management, and save efforts and time that needs for choosing and data interpreting which helps in resources management procedures [24].

Mineral resources are worthy asset of the country, it is the material basis for the national economic and social development, and it is also a significant basis of the production development and the protection for people's living

standard [14]. The development of human society could be based directly on the used quality of mineral resource. With the progress of science and technology, in addition to the global population growth in developing of modern societies, the exhaustion speed of mineral wealth has become very fast, while mineral wealth mining has become progressively sophisticated because of the enhancement of the degree of geological endeavors [14].

For protecting mineral wealth and the environment, it is important to increase protection and adhere to using comprehensive mineral resources to supply nerves and aid the management of mineral wealth [14]. However, the present fundament authorities have some shortage such as: the unsatisfactory level of information, the tardiness of business office techniques the inefficient use of data, even if some areas acquire the information administration with least sharing of the resources, the current systems are based only on proper handling of the document, major number of these maps are traditionally managed (i.e. its management depends on paper). Unlike, the management of digital maps is not appreciated by many of the users and decision makers. Management of mineral resources information may be utilized by developing the GIS systems to manage these resources. Decision makers have to be creative in handling convenient procedure technique by enhancing the incorporated mineral wealth management; this may improve the quality and data handling speed, decrease the hindrance of the staff and enhance the degree of human effort [28]. How to utilize the specialized GIS techniques such as computerized mining and computer programming language to consolidate management system of mineral resources has turn into one of the pressing issues of the mining authority [14].

The need for information services adequate for the mineral resources management in specific or special mineral sectors is a must to accomplish sustainable exploitation of the mineral resources, as requested by the administrations, mining companies and the society at large [7]. In many researches GIS were used in planning the future sustainable development of these natural and mineral resources [16].

Jordan country is considered as a very rich country with its huge resources such as: economic, human, and natural. In Jordan development process, these diverse resources represent a very significant role especially in the national income. The resources need a good care, observance, and a lot of labors in order to accomplish best ceaseless maintenance and utilization. The developed GIS system has many features such as: cost reduction of maps development, minimization the used time, and save most of the productions expenses, because it is constructed and built automatically. Moreover, It contributes

in constructing the digital maps with a very low error percentages in compare with the traditional maps created by human. Further details of the developed system will be coming with next sections.

3.   The   Jordanian   Mineral   Resources Geographical Information System (JMR-GIS)

This section describes a developed system which called The Jordanian Mineral Resources Geographical Information System (JMR-GIS). It is a geographic information application that helps the user to know what are mineral resources exist in Jordan and where they are. This system enables the users to select particular type of metallic, particular region, and query type they want to be applied on the selected or queried area.

As in one of the most related to this work, Bataineh and Abualigah [24] mentioned that the GIS in Jordan is used as a very significant information technology tool which is mostly used in enhancing and supporting the management of resources. Jordanian government legislated some of the sustainable development policies that support in conceiving a lot of significant information and help the Jordanian national information system via focusing on the following policies [24]:

    1. The important role of the resources management in Jordanian development

    2. The management of the mineral resources and the systems of information geography

    3. The GIS should be used in producing the Jordanian minerals information.

The developed system has a local tool, based on a framework for the collection of the available mineral data and its conversion into an accessible information system. The system has 12 layers of information, focused on one main topic "Jordanian Mineral Resources": two layers of Jordan-boundaries and streets-and-roads were installed from ESRI website. Then ten additional layers –for the mineral resources- using ArcGIS and ArcCatalog were prepared and added. The ten layers as follows: one for Jordan cities and nine for the mineral resources in Jordan, namely they are:

- الفوسفات   (Phosphate)
- الاسمنت   (Cement)
- الحديد   (Iron)
- النحاس   (Copper)
- حجارة البناء (Building Stones)
- رمل الزجاج (Sand Glass)
- الجبص   (Gypsum)
- الصخر الزيتي (Shale)
- آبار بترول استكشافية (Exploratory Oil Wells)

The main objective of this work was to collect an available data on mineral resources and environmental aspects of Jordan, integrating this information into a useable, easily accessible system for the decision makers. The layers of the developed system were prepared using software component library called ArcGIS Desktop which will be introduced in the next section.

4. ArcGIS Desktop

Recently, the market of GIS packages has under-gone a remarkable variation and evolving. The number of commercial GIS packages has grown considerably, while their costs have decreased spectacularly [12]. Most of them were constructed and developed to be compatible with different hardware platforms and various users' needs. [15]. ArcGIS Desktop is a scalable standard productivity tool for manipulation geographic data [11]. ArcGIS is a desktop GIS implementation of a consolidated software package. It involves a set of user interface components with windows desktop applications (such as: ArcCatalog, ArcMap, and ArcToolbox).

New functionalities can be appended to the standard via a set of ArcGIS Desktop expansions from ESRI and other organizations (edndoc.esri.com). ArcObjects is a software component library offered in ArcGIS, which can be used to enable the users to enhance their own functionalities. Componentized ArcGIS embeds more modern and sophisticated technique. These components are robust and more adequate for further development which can be developed and expanded continuously. ArcGIS offers typical GIS functions and tools such as: manage location-based data, spatial data analyzing, categorical data analysis, multi-source images processing, and map updating. ArcGIS is compatible with several programming languages such as C#, because it is designed to be a component-based GIS software development tool.

The components of ArcGIS are not dependent on the used programming language. The functions of GIS can be implemented by embedding the components within a specific general developing environment. Further peculiar function can be achieved either by adding other vocational components or by specific general developing environments.

5. Developing Environment

The incorporation of GIS techniques and understand the developing language for the minor development is today's prevailing GIS system development. Advantages of other language can be used by GIS tools such as proper programming and highly efficient, make the directors not only be able to raise the competency of the development of application systems where the system will has superior appearance, easy to maintain, more robust database functionalities because the software development tools can use the visualization capability [14].

Any GIS application and/or operation contain(s) five essential elements: data acquisition; preprocessing; data management; manipulation and analysis; and product generation [1] [4] [23] Data acquisition means distinguish and collect the required data of the application. This data especially the environmental ones can have different formats such as tabular or digital maps. After acquisition the required data, then the set of steps called pre-processing phase is executed by transforming a dataset into a appropriate format for the GIS data inputs. The main step of preprocessing phase is the conversion of data format such as maps' digitization and storing the information into spatial databases. It also involves: data generalization and reduction, error detection, map projection and interpolation [3]. Mainly, data sets are processing before and after computerized in order to be referenced by a shared geodetic coordinate (such as UTM), scale and orientation [3]. The developed system utilizes the above five steps as a development methodology.

Therefore, management of mineral resource is greatly depends on the GIS technology by modelling the mineral data in order to solve and manage the problems associated with mineral wealth. The paper presents a Jordanian Mineral Resources Geographical Information System (called JMR-GIS) that has been developed in order to manage the mineral data locations which are stored into mineral resources database and to consolidate/visualize some spatial datasets. JMR-GIS has been built based on ArcGIS framework. It accommodates a large number of spatial data at Jordanian territorial levels.

To prepare the digital map, the Jordan map is installed from the ESRI website with a full featured mapping control that make it easy for a .NET Developer to add a mapping functionality to a .NET application quickly and efficiently. Using the conjectural object model, even novel developers in GIS can have fully functional maps working in a very short time [25]. Based on the engine of ESRI's ArcGIS, the interfaces of the users were constructed to process, visualize, and simulate results on the digital maps.

The engine of ESRI's ArcGIS is mainly selected as a GIS development environment, because constructing of customized GIS and workable by the users from scratch is not any easy task. ESRI fired the Engine of ArcGIS as the first product that

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assists users to obtain the ArcObject which is the main functionality of ArcGIS beyond the integrated development environment of ESRI.

The JMR-GIS passed through two phases: the first phase is preparing the map, and the second phase is developing the application based on the map from the first stage. In the first phase the ArcGIS and ArcCatalog Software were used. While in the second phase, the system is developed using C# programming language, in addition to use a trial version of software called Desktop Map Suite (which is simply a two DLL files support .net programmers with set of controls and function helping them in dealing with maps and developing spatial applications).

5.1 Phase 1 (Preparing the Database)

The used map in the developed system is organized as set of layer, this layering strategy is very important so the developer become able to select, add, and delete features to the map (In other words, it will be scalable). To prepare and use the intended map, Jordan map is installed from the ESRI website as mentioned before.

In fact, each layer is stored as shape file which is a common of data format geospatial vector for GIS. These layers are built and diversified by ESRI as an open environment for data to be able to be exchanged between general software products and ESRI. A "shapefile" commonly refers to a collection of files with ".shp", ".shx", ".dbf", and other extensions on a common prefix name (e.g., "rivers.*") [25]. Files with ".shp" extension are related accurately to the actual shape file. Unlike, this file is not complete in order to be useable, because other auxiliary files are required. Moreover, .dpf file is a database file which stores the information about characteristics. While the file with .shx extension is an index that acclimated to access the achievement and decrease the time bare to retrieve data.

The Author of this paper draw the ten layers described above base on "Jordan map for mineral resources" from "Atlas of Jordan and The world". ArcCatalog software is used to create the shape files and specify the corresponding relations field, and then based on these shape files ArcGIS was used to edit these files and add the necessary features; all shape files of the developed system are stored in folder called Database which used directly from the developed system.

5.2 Phase 2(developing the application)

ESRI package provide mining firms the geographic feature to pursue possible mineral, probing geoscientists to use different kinds of datasets to look for deposits in their mineral exploration. They need to analyze and browse this information

easily and rapidly. ESRI presents this data in an easy way to use tools and software applications, stepping up the spatial sequence of the available information to mining planners and providing them sturdier understanding of the expected locations [6]. Probing targeting may be carried out on the base of progressive analysis utilizing either quantitative or qualitative techniques. Numerous geophysical images may be viewed concurrently at the same time using ArcMap coated by other datasets to assess the quality of their spatial relations. The spatial analyst extension of ArcGIS in ESRI can be used by geologists to compute the possible of mineral locations by algebra of raster based map using either techniques driven by data or knowledge [6].

As mentioned at the begging of this section, the system is developed using C# together two DLL files namely: MapSuiteCommon.dll and DesktopEdition.dll. These files support developer with set of data types, controls and functions that are very useful in developing GIS applications. When the programmer adds the references for these files he can create maps and deal with it smoothly and easily.

6. How to use Jordan Mineral Resources Map

Figure 1 represents the main interface the developed system which consists of 6 main areas as follows:
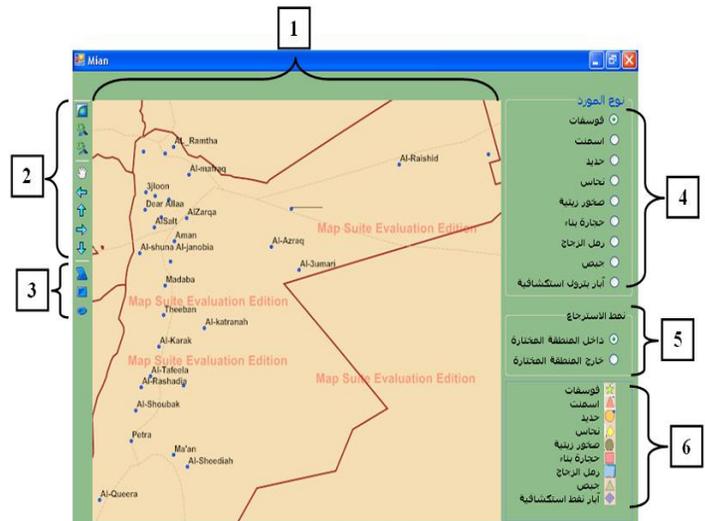
Fig. 1 The Components of the Main Interface

Area 1: represents the Jordan map which shows the border and the main cities, and it will be used to show the exact location of the mineral resources.

Area 2: represents the first toolbar which provides the user with set of operation that help him to deal with the map, resize it and select the desired area over

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which the query will be executed , it contains the following buttons

- o Full context : return the map to its default size
- o Zoom in
- o Zoom out
- o Pan: for pan mode
- o Pan left
- o Pan right
- o Pan up
- o Pan down

Area 3: represents the second toolbar which provides the user with his capability to choose the shape of the area on the map that he want to query about. There are three shapes as follows:

- o Polygon window : select polygon-shape area
- o Rectangle window : select rectangular area
- o Ellipse window : select ellipse-shape area

Area 4: this area enables the user to select the resource type (نوع المورد) using the radio buttons, as seen before there are 9 mineral resources.

Area 5: in this area there are 2 retrieving style: the first style is (داخل المنطقة المختارة) inside the selected area, while the second style is (خارج المنطقة المختارة) outside the selected area.

Area 6: this is area is just a legend which shows the shape for each one of the nine mineral resources.

User can select the resource type (نوع المورد) using radio button on the right side of the main screen (area 2), then he can select the type of query he want to apply on this area. After that the user select the area using area selecting buttons (polygon window, rectangle window, and ellipse window), based on the query type all the resources instance that are available in the selected area will appear using special shape and color. As you can see in area number 6, every resource has its own shape and color as in the map legend. For example iron is displayed as orange circle.

To know how the developed system does work, let us take the following two simple examples:

Example 1:
Figure 2 shows the map after selected parameters were set:

The shape of the area: Rectangle
The type of mineral resource: الفوسفات (Phosphate)
The retrieving style: داخل المنطقة المختارة (inside the selected area)
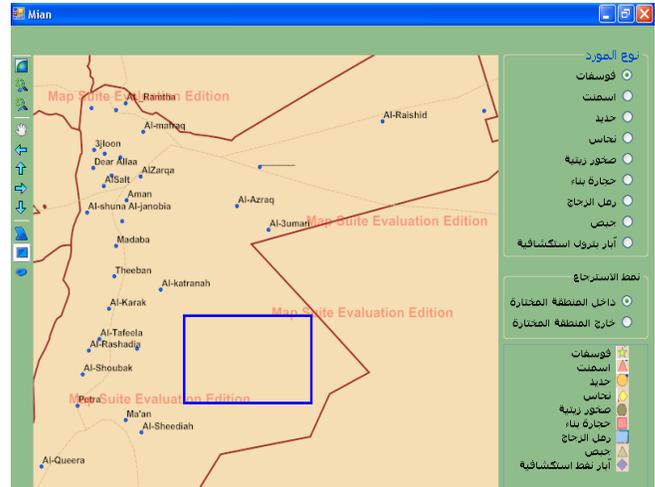
Fig. 2 Negative response- Resource is not found

As you can see, inside the selected area there is no Phosphate. This example shows the negative response of the system (when there is no resource found inside the selected area.

Example 2:
Figure 3 shows the map after selected parameters were set:

The shape of the area: Rectangle
The type of mineral resource: حديد (Iron)
The retrieving style: داخل المنطقة المختارة (inside the selected area)
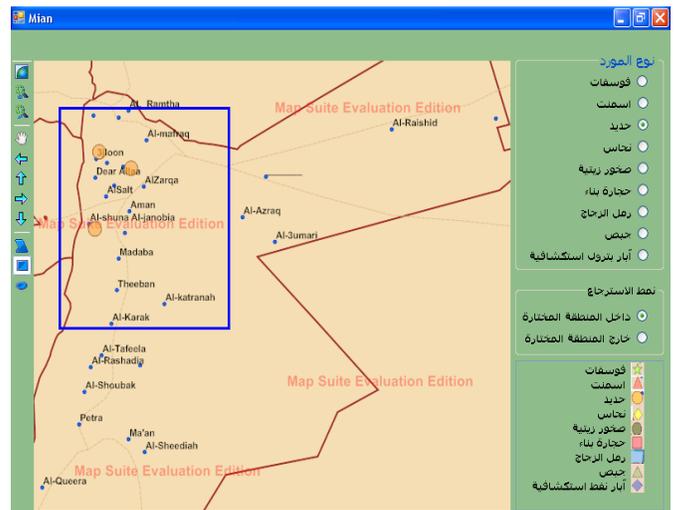
Fig. 3 Positive response- Resource is found

After the previous parameters were set, it obviously can see that there are three locations that have the Iron resource inside the selected area by the rectangle.

7. Conclusions

GIS are growing increasingly as a complementary component of mineral wealth administering activities in the whole world. Moreover, there is a significant functional in the existing attitude information and the consummation management of mineral resources by information technology. The processing of intricate non-spatial and spatial data in a complementary approach achieves a significant part of GIS functionalities. In addition to the capability of analyzing and modeling, various relationships between datasets by the means of these models may lead to be utilized and developed to start more certain tasks like mineral possible mapping. The developed system is scalable and flexible (it is able to use by advanced systems). In other words, it can accept any additional number of layers and dataset easily. Thus, the work will be the first step to computerize mining of the Jordanian mineral resources. So, in the near future this system can be used by add the data mining or neural networks techniques to mine the mineral resources electronically.

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