ORIGINAL ARTICLE

DEVELOPMENT OF A DATASET FOR DATA MANAGEMENT OF GEOLOGICAL MAPS OF MOROCCO

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ABSTRACT

Background: GIS (Geographic Information System) software is modern IT tools suitable for the effective and timely management of geographic data. However, they include DBMS (database management systems) for creating and managing spatial geographic database, called Geodatabase. **Method:** From the consultation of data from geological maps, a specific methodology was adopted. It is based on the identification of thematic layers, establishment of attributes and vocabularies, definition of the types of relationship between the tables used and finally on the specification of the topology. **Result:** The created personal geodatabase called Geology.mdb contains a set of feature classes UG (Geological Unit), which includes eight classes of entities associated with a table (GMAP), which informs about the geological map via a relationship "One to Many". **Conclusion:** The Geodatabase Geology.mdb is scalable and interoperable. It allows presenting a harmonized database in a physical structure at the national level.
Keywords: *SGBD, Geodatabase, Dataset, Feature Class, Geological maps, Morocco.*

1. INTRODUCTION

These last decades, GIS (Geographic Information System) and spatial database management systems have been widely developed to manage and analyze spatial data [1]. Many studies apply GIS as a tool to identify or develop existing data on geological maps (ages, lithology...) and field measurements (pendage, direction, embedding, GPS (Global Positioning System) values, ...) to develop a database with the spatial location and relationships linking these data.

The purpose of this study is to create a spatial database in a Geodatabase environment. It allows creating coordinated relationships between feature classes, which allow the creation of domains or lexicons thus reducing errors when entering data and subsequently creating maps with attribute tables and spatial information.

The GIS approach has considerable potential for valuation analysis for geological map data. Previous work proposes geological maps in the form of georeferenced raster products (pixel maps) that do not fully meet the needs of users in terms of geoprocessing and spatial analysis. It is therefore important to use digital data from geological maps at the spatial entity level and to define its relationships and topology. This geodatabase structured provides the ability to process both spatial and descriptive information in a single application where geographic information is organized into a series of data layers that can be integrated using the geographic location.

2. MATERIALS AND METHODS

2.1 Software

The design of this application required the use of:

• Geological maps at scales of 1: 50,000 and 1: 100,000 (Moroccan Geological Survey) and documents provided by the State Secretariat responsible for the development of the mining sector;
• The software used are: Microsoft Access 2007 to create a graphical representation of the relationships between the tables (primary key and foreign key), ArcGis Diagrammer to generate in a simple way a Geodatabase that can be imported as an XML file by more in ArcCatalog from ArcGIS. This file can be viewed with ArcGis Deseigner software.

II.2 METHODS

The geodatabases have the functionality of relational databases, while integrating spatial data [3]. These characteristics of arrays and relationships represent real world space, time, and descriptive attribute interactions [4].

It is therefore logical that the Geodatabase begins with the identification of the data themes to be used, then with the specification of the content and representations of each thematic layer.

This involves adopting the following approach:

-Identify the necessary geological thematic layers that present a decomposition of the complexity of the real world (Dataset), (feature classes) and establish the fields (attributes) from the consultation existing documents:
-The geological maps published by the Geological Survey of the Minister of Energy and Mines of Morocco at different scales;
-The practical guides of the geological maps elaborated as part of the National Geological Mapping Plan (PNCG-Morocco) and which meet the geological norms (lithological nomenclature, metamorphic facies, ...);
-Define the spatial representation (point, polygon, line, or table) and the spatial reference (Datum, projection);
-Determine the domains or lexicons table that define the allowed values for a given field in a feature class or non spatial attribute table. If entities or non spatial objects have been grouped by subtype, several attribute domains can be defined for each subtype. There are two types of domains in the Geodatabase: (1) precoded value domains (acceptable values for an feature class) and (2) range domains (acceptable ranges for attribute fields).). These areas are intended to reduce errors when entering data;
-Create relationships that define how rows in one table can be associated with rows in another table (one-to-one, one-to-many, or multiple-to-many) by specifying primary keys and foreign keys;
-Define the topological relationships that allow the description of the geometric relationships between the entities used;
-Structure the data model using the ArcGis Diagrammer software and develop an XML file;
-Import the XML file by ArcCatalog into the ArcGIS software. This file can be viewed with ArcGis Designer.

4. DISCUSSION

4.1 Geodatabase structure

Geodatabase: The data model presented here was built in a personal Geodatabase. It is similar to the coverage data model. This Geodatabase is named Geology.mdb and includes a single Dataset named by Geological Unit. This dataset gathers a list of Feature Classes representing layers of geological data. All feature classes have the same geometry (point, line, polygon,) and the same attributes in a Lambert Morocco coordinate system and a table (GMAP) gives information about the geological map used subsequently linked to the classes of entities of the same Geodatabase. These attributes have topological relationships.

"**Geological Unit" dataset**: The dataset concept is similar to the notion of coverage. Indeed, a cover contains several feature class in point, line, polygon, annotation shape. In our data model we have named the Feature Dataset by Geological Unit and it has 8 Feature class.

Feature classe: The feature classes described in the data model below consider both the type of geological feature, and the spatial representation of that feature. Table 1 shows the eight feature classes defined in this study with their description. For example, the Magmatic Geological Unit (UG_MGT) can be represented by a zone (polygon) (Table.1).

"GMAP" table: A table can be stored in a Geodatabase. It is characterized by a set of fields and records. Tables in a Geodatabase can be linked or joined to tables or feature classes in the same Geodatabase. For this study, a table summarizing the information from the geological map used (Table.2) was used.

Domains: define acceptable values for attribute fields in tables in the Geodatabase. In this data model we used the precoded domains that describe a code list with their description: for example the notation of the systems that designate the subdivision of an eratheme on the geological time scale (QUA, NEO, PAL, ...) and their equivalents (Quaternary, Neogene, Paleogene, ...) and which are subsequently linked to the attribute fields of the feature classes [3,4] (Table.3). In the data dictionary, attribute domain values are listed along with their associated description. These domains contain a list of information from which the operator must make a choice. A domain contains a list. During the input stage, the domain presents itself in the form of a drop-down menu. This function also avoids input errors.

Subtypes: are subsets of features in a feature class or objects in a table that share the same attributes. They are a method of categorizing data. The subtypes used in this work are for the Geological Contact (CG) feature class. These subtypes define the information that can have the attribute of contact line types (CG_SUB). Thus for the Magmatic Geological Unit (UG_MGT) feature class, where there are four subtypes (Felsic intrusive rock, Intermediate intrusive rock, Mafic intrusive rock, Ultramafic / ultrabasic intrusive rock) for the attribute that designates facies types. plutonic (FCS_PLT), and they are subsequently associated with their domain (RIF_TYPE; RII_TYPE; RIM_TYPE; RIU_TYPE) [3,4] (Figure 1).

Relationship classes: store information about how objects are linked, such as tables and feature classes. For this data model, relationship classes are used to link a feature (eg Magmatic Geological Unit, Age Geological Unit, etc.) to its source map information (GMAP). For each relationship classes in the data dictionary, the following elements are presented: the name, the type of relation (composite or simple), the cardinality rule (one-to-one, one-to-many, several-to -one or many-to-many) and the origin and destination of objects with primary and foreign key fields. In this Geodatabase, relationships are simple, one-to-many relationship stored in a set of data used to link the table (GMAP) to feature classes (Figure 2).

Topology rules: The Geodatabase stores feature classes of points, lines, or polygons. Because shape of the entities and their location, have spatial relations between them. The description of these geometric relationships between entities is called topology. In order to create a topology, the participating feature classes must be in the same Dataset and it has a common spatial reference. Table 4 shows the three types of topology developed for this study and their description. For example, the contours of the geological age units (UG_Age) must be covered by the Geological Contact (CG) feature class, or the spatial shapes presented by a polygon of the same feature class (UG_Age) must not be overlaid (table 4).

Table 1: List of feature classes with spatial types and their descriptions.

Entity class	Abbreviation	Spatial type	Description
Geological Unit Age	UG_Age	Polygon	A unit corresponding to the hierarchical terrain by geological time
Geological Unit of Formation	UG_FRT	Polygon	A surface unit that designates formations
Geological tectonic unit	UG_TCT	Polygon	A surface unit denoting any set of terrains that can be individualized for tectonic reasons called tectonic units
Metamorphic Geological Unit	UG_MET	Polygon	A unit designating any set of metamorphic terrains
Magological Geological Unit	UG_MGT	Polygon	A unit designating any set of magmatic lands
Geological unit as a point	UGP	Point	A geological unit in the form of points. This is off the scale of the original map.
Geological Contact	CG	Line	A unit that presents the outer boundary of a polygon feature of a geologic unit.
Sampling and dating micropaleontology	PDM	Point	It is an entity that presents the different types of micropaleontology (Macrofaune, Microfauna, ..) that allow the dating of layers

Table 2: The fields of the GMAP table with the abbreviations used and their description.

Field name	Abbreviation	Description
Source map_ID	GMAP_ID	A long integer value that has an organizational identifier (Exp an ISSN number).
map name	GMAP_NOM	Name of the map used
Author of the map	GMAP_AUT	Name of the authors of the map
Note and Memory	GMAP_NOTES	Number of notes and memoirs of the geological service Morocco
Completed model	GMAP_MAQ	Model number completed in case the map is not yet published or unpublished
Scale	GMAP_ECH	scale of the geological map
Projection	GMAP_PROJ	Name or description of the map projection
Document consulted	GMAP_DC	Documents and works in case the geological map appears on a thesis or a new document
Lifting carried out	GMAP_LE	Lifts made for the geological map
Field study	GMAP_ET	Authors' names for field studies

Table 3: The types of domains used with their abbreviations and the attributes of the feature classes associated with these domains, (* Denotes a domain associated with a subtype).

Domain name	Abbreviation	Entity class (Attribute field)
Éon	EON_TYPE	UG_Age (Eon_UG_AGE) UG_FRT (Eon_UG_FRT) UG_TCT (Eon_UG_TCT) UG_MET (Eon_UG_MET) UG_MGT (Eon_UG_MET)
Color of the Éon	EON_TEINTE	UG_Age (TNT_ Eon_UG_AGE) UG_FRT (TNT_ Eon_UG_FRT) UG_TCT (TNT_ Eon_UG_TCT) UG_MET (TNT_ Eon_UG_MET) UG_MGT (TNT_Éon_UG_MGT)

Èra	ERE_TYPE	UG_Age (Ere_ UG_AGE) UG_FRT (Ere_ UG_FRT) UG_TCT (Ere_ UG_TCT) UG_MET (Ere_ UG_MET) UG_MGT (Ere_ UG_MGT)
Color of the Èra	TEINTE_ÉON_TYPE	UG_Age (TNT_ Ere_ UG_AGE) UG_FRT (TNT_ Ere_ UG_FRT) UG_TCT (TNT_ Ere_ UG_TCT) UG_MET (TNT_ Ere_ UG_MET) UG_MGT (TNT_ Ere_ UG_MGT)
System	SYS_TYPE	UG_Age (SYS_ UG_AGE) UG_FRT (SYS_ UG_FRT) UG_TCT (SYS_ UG_TCT) UG_MET (SYS_ UG_MET) UG_MGT (SYS_ UG_MGT)
Color of the system	TEINTE_SYS_TYPE	UG_Age (TNT_SYS_ UG_AGE) UG_FRT (TNT_SYS_ UG_FRT) UG_TCT (TNT_SYS_ UG_TCT) UG_MET (TNT_SYS_ UG_MET) UG_MGT (TNT_SYS_ UG_MGT)
Subsystem	SSYS_TYPE	UG_Age (SSYS_ UG_AGE) UG_FRT (SSYS_ UG_FRT) UG_TCT (SSYS_ UG_TCT) UG_MET (SSYS_ UG_MET) UG_MGT (SSYS_ UG_MGT)
Color of the Subsystem	TEINTE_SSYS_TYPE	UG_Age (TNT_SSYS_UG_AGE) UG_FRT (TNT_SSYS_ UG_FRT) UG_TCT (TNT_SSYS_ UG_TCT) UG_MET (TNT_SSYS_ UG_MET) UG_MGT (TNT_SSYS_ UG_MGT)
Stage age	ETG_TYPE	UG_Age (ETG_ UG_AGE) UG_FRT (ETG_ UG_FRT) UG_TCT (ETG_ UG_TCT) UG_MET (ETG_ UG_MET) UG_MGT (ETG_ UG_MGT)
Color of the stage age	TEINTE_ETG_TYPE	UG_Age (TNT_ETG_ UG_AGE) UG_FRT (TNT_ETG_ UG_FRT) UG_TCT (TNT_ETG_ UG_TCT) UG_MET (TNT_ETG_ UG_MET) UG_MGT (TNT_ETG_ UG_MGT)
Ensemble of the stage age	ESL_ETG_TYPE	UG_Age (ESL_ETG_UG_AGE) UG_FRT (ESL_ETG_UG_FRT) UG_TCT (ESL_ETG_UG_TCT) UG_MET (ESL_ETG_UG_MET) UG_MGT (ESL_ETG_UG_MGT)
Type of lithology	LITH_TYPE	UG_Age (LITH_PR_UG_AGE;LITH_SC_UG_AGE) UG_FRT (LITH_PR_UG_FRT;LITH_SC_UG_FRT) UG_TCT (LITH_PR_UG_TCT;LITH_SC_UG_TCT) UGP (LITH_PR_UG_UGP ;LITH_SC_UG_UGP)
Appearance of a point	POINT_POS	UGP (POS_UGP) PDM (POS_PDM)
Appearance of a line	CNT_POS	CG (POS_CG)
Type of Tectonite Rocks	TT_TCT_TYPE	UG_TCT (TT_TCT)
Metamorphic facies	FCS_MET_TYPE	UG_MET (FCS_MET)
Metamorphic rock	TR_MET_TYPE	UG_MET (TR_MET)
Magmatic rock type	TRM_MGT_TYPE	UG_MGT (TRM_MGT)
Felsic Intrusive Rock Type	TP_RIF *	UG_MGT (FCS_PLT)
Intermediate intrusive rock type	TP_RII *	UG_MGT (FCS_PLT)
Type of mafic intrusive rock	TP_RIM *	UG_MGT (FCS_PLT)
Type of intrusive ultramafic / ultrabasic rock	TP_RIU *	UG_MGT (FCS_PLT)
Type of fauna (macrofauna, microfauna, ...)	FAUNE_TYPE	PDM (PDM_FAUNE_TYPE)
Fossil type	FSL_TYPE	PDM (PDM_NAME_FSL)

Figure 1: The attribute table of the magmatic geological unit (UG_MGT) feature class with the Era-coded domain table and annotations and the associated felsic intrusive rock-type domain for one of the plutonic facies attribute subtypes.

Nom du Champ	Abréviation	Types de Données	Valeurs Nuls	Domaine	Précision	Echelle	Longueur
OBJECT_ID*	OBJECT_ID	ID de l'objet	---	---	---	---	---
SHAPE*	SHAPE	Géométrie	Oui	---	---	---	---
Feature ID	UG_MGT_ID	Entier Long	Non	---	0	---	---
Éon	Eon_UG_MGT	Texte	Non	Pré-codéee	---	---	---
Teinte Éon	TNT_Eon_ UG_MGT	Texte	Non	Pré-codéee	---	---	---
Ére	Ere_UG_MGT	Texte	Non	Pré-codée	---	---	---
Teinte Ère	TNT_Ere_UG_MGT	Texte	Non	Pré-codée	---	---	---
Système	SYS_UG_MGT	Texte	Non	Pré-codée	---	---	---
Teinte Système	TNT_SYS_UG_MGT	Texte	Non	Pré-codée	---	---	---
Sous-système	SSYS_UG_MGT	Texte	Non	Pré-codée	---	---	---
Teinte Sous-système	TNT_SSYS_UG_MGT	Texte	Non	Pré-codée	---	---	---
Etage	ETG_UG_MGT	Texte	Non	Pré-codée	---	---	---
Teinte Etage	TNT_ETG_UG_MGT	Texte	Non	Pré-codée	---	---	---
Ensemble d'Etages	ESL_ETG_UG_MGT	Texte	Non	Pré-codée	---	---	---
Age en Ma	AGE_UG_MGT_MA	Réel simple	Non	---	6	3	---
Type de roche magmatique	TRM_MGT	Texte	Non	Pré-codée	---	---	---
Faciès plutonique***	FCS_PLT	Entier Long	Non	Sous-Type	0	---	---
Type de Roche plutonique	PLT_TYPE	Entier Court	Non	Précodéé	---	---	---
Roche volcanique Felsique	RVF	Texte	Non	Précodéé	---	---	---
Roche volcanique intermédiaire	RVI	Texte	Non	Précodée	---	---	---
Roche volcanique mafique	RVM	Texte	Non	Précodée	---	---	---
Roche volcanique ultrabasique/ultramafique	RVU	Texte	Non	Précodée	---	---	---
Notes	NOTES_UG_MGT	Texte	Non	---	---	---	254
Source Carte ID**	GMAP_ID	Entier Long	Non	---	0	---	---
Shape_Length*	SHAPE_Length	Double	Oui	---	0	---	---
Shape_Area*	SHAPE_Area	Double	Oui	---	0	---	---

Domaine : Valeur pré-codéee	Définition
CE	Cénozoïque
ME	Mésozoïque
PA	Paléozoïque
PR	Protérozoïque
NP	Néo-Protérozoïque
MP	Méso- Protérozoïque
PP	Paléo-Protérozoïque
NA	Néo-archéen
MA	Méso-archéen
PA	Paléo-archéen
EA	Eo-archéen

Valeur Sous-type	Définition	Domaine Associé pour FCS_PLT
0	Roche intrusive felsique	RIF_TYPE
1	Roche intrusive intermédiaire	RII_TYPE
2	Roche intrusive mafique	RIM_TYPE
3	Roche intrusive ultramafique / ultrabasique	RIU_TYPE

Domaine : Valeur pré-codéee	Définition
1	IIA_Granite à feldspath alcalin
2	IIB_Granite
3	IIC_Granodiorite
4	IID_Tonalite
5	IIE_Trondhéjémite
6	IIF_Aplite
7	IIG_Pegmatite (granitique)
8	IIH_Granophyre
9	III_Granitoïde riche en quartz
10	IIJ_Quartzolite (silexite)
11	IIK_Alaskite
12	IIL_Syéno-granite
13	IIM_Monzo-granite
14	IIN_Filon/veine de quartz
15	IIO_Granite à feldspath alcalin avec hypersthène (charnockite à feldspath alcalin)
16	IIP_Granite à hyperthène (charnockite)
17	IIQ_Syéno-granite à hypersthène
18	IIR_Monzo-granite à hypersthène (farsundite)
19	IIS_Granodiorite à hypersthène (opdalite ou charno-enderbite)
20	IIT_Tonalite à hypersthène (enderbite)

Figure 2: Graphical presentation of the structure of the Geodatabase with the relations between the tables.

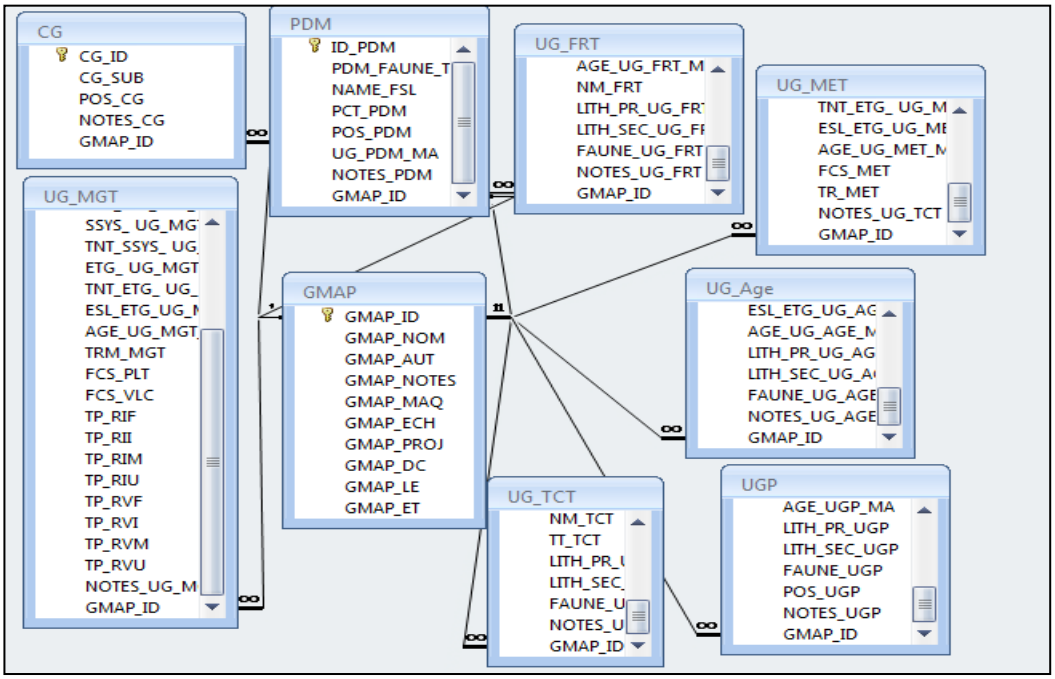


Table 4: the topology between the age unit geological unit (UG_Age) and the geological contact entity class (CG)

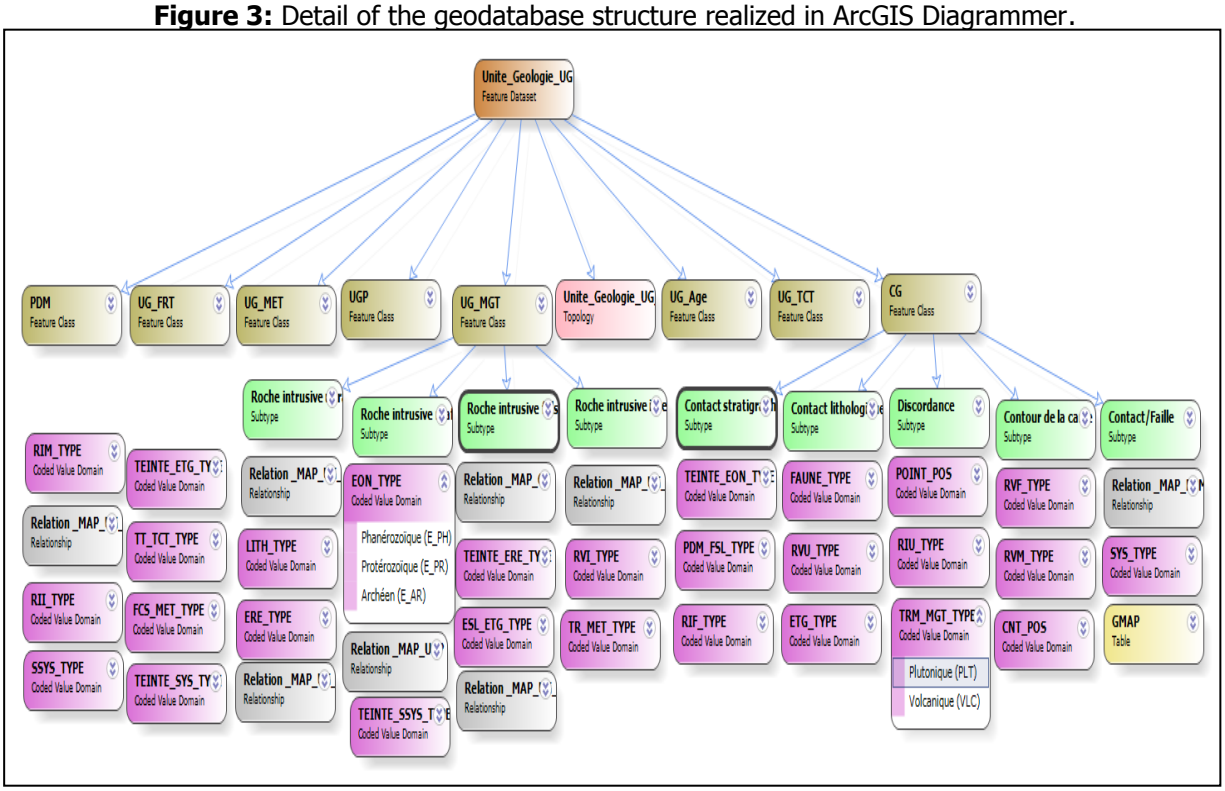
Role of Topology	Origin: Feature class subtype	Destination: Feature class subtype
Must not have discontinuities	UG_Age - Tout	UG_Age – Tout
Must not overlap	UG_Age - Tout	UG_Age – Tout
Contours should be covered	UG_Age - Tout	CG- Tout

4.2. Creation of Godatabase

4.2.1 Realization of the structure with the Esri ArcGIS Diagrammer tool:

The free tool "ArcGIS Diagrammer" allows us to generate a Geodatabase that can be imported later in ArcCatalog [6]. The principle is to create a diagram composed of Feature dataset, feature class, tables and topology rules and to fill in all the information concerning them (Figure 3): projection system, geometry of feature classes, relationship type. The interest lies in the execution and the possibility of making modifications. For example, in contrary to ArcCatalog where you must delete a field to modify it ArcGIS Diagrammer allows you to make the change directly in the Properties window of the entity class in question. When the structure is complete and any errors have been corrected, the diagram can be imported via the Html format into ArcCatalog.

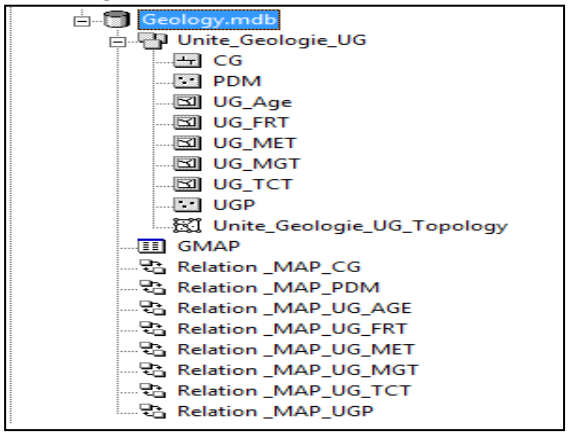
Figure 3: Detail of the geodatabase structure realized in ArcGIS Diagrammer.



4.2.2 Import a geodatabase into ArcCatalog and ArcMap:

Once imported, the Geodatabase tree unveils the UG (Geology Unit) dataset, the eight feature classes, and (GMAP) table that match the geodatabase structure "Geology.mdb". For the moment, the Geodatabase is like an empty shell: the structure, the names and types of fields, the relations are filled in but the data are missing. Figure 4 shows this state of affairs with the UG (Geology Unit) dataset and the feature classes, which do not yet contain a record. The next step is to import existing data, and to digitize entities for old information in ArcMap. Thus, the Geodatabase will be definitively operational.

Figure 4: Geodatabase structure « Geology.mdb » in ArcCatalog.



4.2.3 Visualization of XML in Geodatabase Designer

This tool makes it possible to export and import the complete structure of a Geodatabase (Classes of objects, Classes of relation, Domains, geometric networks ...) [7]. It allows updating, visualizing or applying a Geodatabase structure. The import and export format is XML. These files can be easily viewed by Geodatabase Designer (Figure 5), edited by a large number of third-party applications, and develop an HTML page (Figure 6).

Figure 5: Visualization of XML generated by Geodatabase Designer.

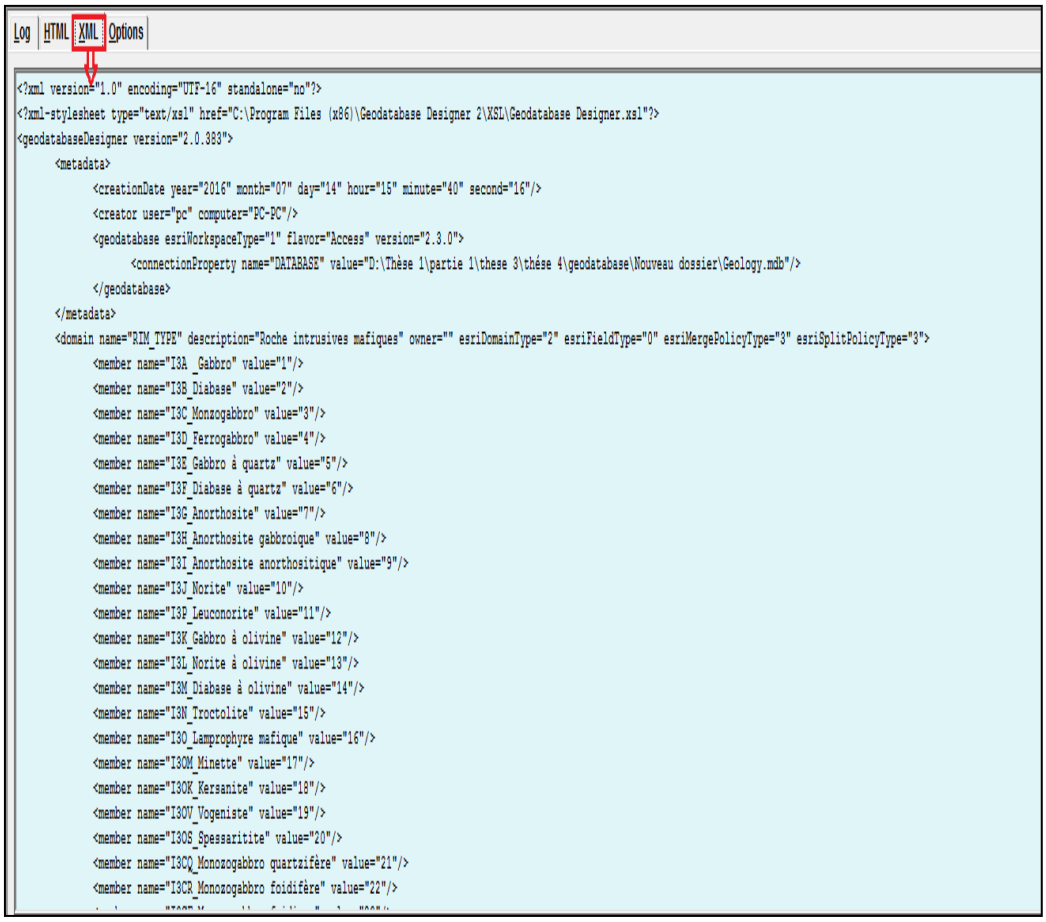
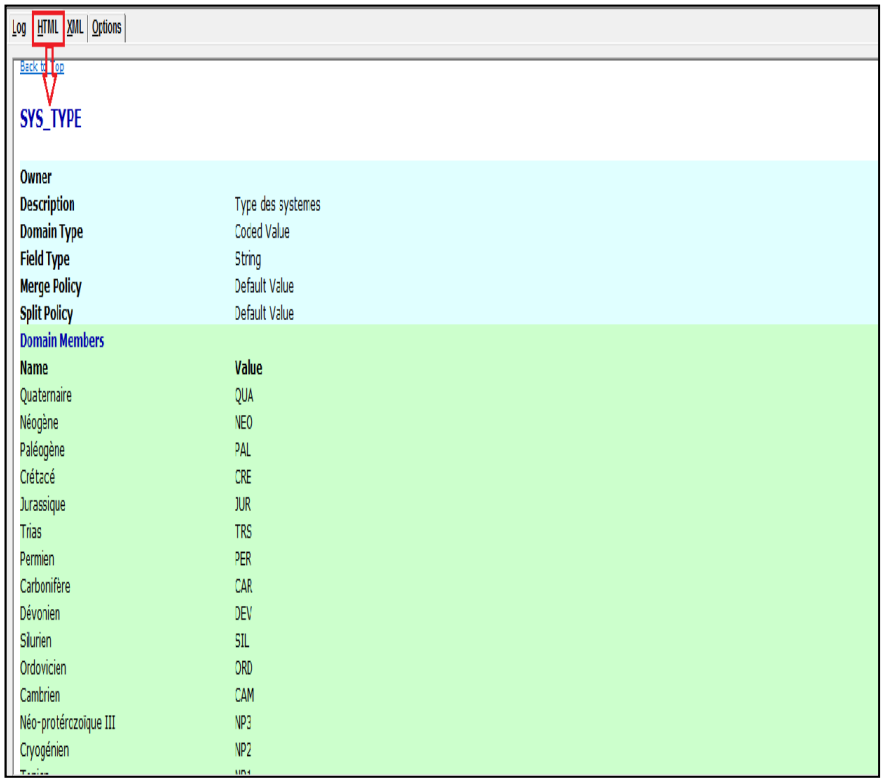


Figure 5: Visualization of XML generated by Geodatabase Designer.



5. CONCLUSION

The purpose of the creation a Geodatabase is to create a foundation for geological digital data management in a map production environment. The ESRI Geodatabase model provides validation tools and methods to ensure high-quality data output for geological maps and digital data dissemination. Geology.mdb will continue to evolve further by adding other datasets (Tectonics, Geomorphology, ...) and make them available to the scientific community.

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List of acronym:

GIS: Geographic Information System
DBMS: Database Management Systems
IT: Information Technology
GPS: Global Positioning System
UG: Geological Unit
CG: Geological Contact
GMAP: The Geological Map
PNCG: Plan of the National Planning Map of Geological Cartographie

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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