On the Geology of Syria

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Mantellic Xenoliths and Their Fluid Inclusions

By

Ahmad Bilal

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PREFACE

PROF. DR. JACQUES TOURET

In the autumn of 1972, I saw Ahmad Bilal, a young Syrian student who had just graduated from Damascus University, coming to my laboratory in Nancy to register for his thesis. Arriving in France as part of a Franco-Syrian cultural programme, he took an accelerated language course and, after a few months, was able to express himself very well in our language. I was then a professor of Structural Geology, although my primary specialty was petrography. Together with a few colleagues from Nancy University and other centres, I developed a completely new method for studying fluid inclusions in rock minerals. This is the subject I proposed to Ahmad, using the example of the enclaves of the Bournac volcano in Auvergne. After one year he obtained his Diplome d'Etude Approfondi, and defended, one year later, his « Thèse de Troisième Cycle », as it was then called. This marks a date in the knowledge of deep fluids, with multiple implications for phenomena as fundamental as the formation of the atmosphere, the mechanism of volcanic eruptions, or the carbon cycle, key to the existence of life on Earth.

In early 1976, I left Nancy for Paris, to join at the University of Paris 7 (now Paris-Diderot) the team of Professor Claude Allègre, leader in France of a new discipline, Geochemistry. Ahmad, who in the meantime had married his wife Fadia and celebrated the birth of his first child, followed me to Paris to prepare his « Thèse d'Etat », on the same theme as his postgraduate thesis. But the search was extensive on an Earth-wide scale, including in particular the recent volcanoes of Syria, which in many ways have many analogies with the volcanism of Auvergne, and defended it in April 1978, the smallest time achieved for such a trajectory.

A. Bilal's Thèse d'Etat, which for years served as the basis for the work of the stable isotope team at the University of Paris 7, could have opened the doors of Higher Academic Education in France to him. He preferred to return to his home country, becoming in a few years a prominent figure at the University of Damascus. Although he continued his work on deep fluids, he was also interested in the most diverse aspects of Syrian geology: remote

sensing, sedimentary basins and oil deposits, seismic and volcanic hazards, hydrogeology, and many others. His fame led him to be called upon as an expert by major international organizations: United Nations, Council of Europe, Arab League, etc...

Over the years, he has thus accumulated a unique experience in his country, the cradle of our civilization, now torn apart by war. Keeping out of politics, despite many requests, he achieved the miracle of always continuing his scientific activity, to pass on to future generations the experience of the past. This is the testimony he is giving us today. Syria, a country with a thousand years of history, has experienced other crises. She'll live on!

Jacques TOURET
Member of the Royal Academies of Sciences
and Letters of the Netherlands and Norway

ACKNOWLEDGEMENT

I was thinking of leaving my university, the most important Arab university in many decades, the Damascus University. I truly wanted to concentrate on writing books for young Syrian Arab generations by placing my experience at their disposal, and writing novels characterized by a mix between reality and fiction with an intention of sending messages to these generations about ethics, honest competitiveness, talent and innovation, as well as warning them against other killer identities, which have made the Arab countries an undeveloped world. It is for this reason that my latest book was entitled: “In other terms – killer identities and the Arab future as it is and as others see it”, which is written and should be published soon. At this momentous time, I received a letter from Cambridge Scholars Publishing (CSP) calling upon me to write a scientific book. Thus, I found myself responding positively to their call by proposing a book on the geology of Syria.

The person who corresponded with me from CSP, and whom I had not contacted previously, was a lovely, intelligent and patient lady, Helen Edwards – also a good administrator. She helped and encouraged me through the process until signing the contract.

This work represents an important achievement for me before my last break! Also, it brings me back to the beginning, to that day when I decided to study geology at Damascus University. First, my principal motivation was to help my parents who were tired and struggling to secure our livelihood, education and learning, especially my father who seemed to quickly become very old and ill, due to working long hours and thinking how to ensure that his children be educated. Also, geology was an adventurous field for me: it lets you fly with the universe, with our globe and its contents, at its surface, and its interior, its natural resources, and its catastrophes. But in the first three months of my first academic year at the university, I took an important decision: “I will be a professor at this university, the Damascus university", which I am proud of and thank it forever.

In order to achieve this ambition, I should get the position of assistant, which you can only get if you are the first. I was this first, but how? I told

my students how. It wasn't easy but it was fun. So, my next future step was Paris! Paris was for me the Sorbonne, the polytechnic institutes, the superior schools, the grand schools …, Paris was Pierre and Marie Curie, and other grand scientists and scholars, about whom I wrote. Afterwards, I was a candidate for a grant from the French government, and I flew to Royan to learn French during a stay of less than 6 months. Then, I met my professor Jacques TOURET at Nancy in the autumn of 1974, who with his wife, Doctor Lydie, became our friends and will remain so for ever. I owe them all gratitude.

Less than six years later, I flew back to Syria; and I was nominated a professor at Damascus University. I spent almost a year at Royan, and two years in Nancy to prepare a Diploma (DEA), and specialty Doctorate. Then, I had to move to Paris with my professor, to the "Institute de physique de globe", Paris 6, Paris 7, and the Natural History Museum, where I had to stay less than three years (January 1976 to April 1978), to prepare the Doctorate d'Etat et Sciences. My dear professor Jacques Touret always stayed close to me, as a friend but always with a relationship as a professor and student. He and Lydie, his wife, were always pillars of support to us, and again Jacques has honoured me with writing the preface to this book.

Many others have contributed to my scientific work, or I have benefited from their works in accomplishing this work. This is evident from the proven references list (citations) as required by scientific ethics. Especially among them, in addition of all I used their works on the region as citations, I mention my colleagues: Professor Jean CHOROWICJ (University of Pierre and Marie Curie, Paris 6), with whom and alongside others we established a cooperation project on the basalt of Homs and its tectonics, and together we published a very important paper; Professor Jean Yves COTTIN (University of Jean Monnet-St-Etienne) on the petrology and geochemistry of Djebel El Arab (Tel Thenoun Volcano), with my student Mohamad Ismail (now a professor at Aleppo University) who prepared a Doctorate on this subject, and we published a very important article; Professor Abdul Karim Al ABDALLAH, who wrote a very important thesis on the tectonics of Syria at Pierre and Marie Curie University; and I have used some of his important conclusions in this work. Professor Albert JAMBON (University of Pierre and Marie Curie, Paris 6), with whom we established a cooperation project, and he invited me for a sappatical year offering me all analytical methods and technics of his laboratory, where I published two articles using some partial analysis and Arab antiquities.

Beside these colleagues I got benefit from the works of my Master and Doctorate students, especially Doctors F. Sheleh, R. Youssef, F. Mohamad, A. Kafa, S. Badour, A. Mansour, R. Hamdan, M. Abo Moghdeb. In addition I have benefited from my Master students: I. Taraf, A. W. Al Hamad, O. Abdallah, as well as many who were helpful through their different works: drawing, photography, printing, at Damascus University. Notable among these are Dr. P. Milaneh, Dr. A. Abdalla, and Kamara. Also at Dar Tlas I wish to note especially the director Mr. Batigha, Ibtissam and Bassel, who are all dear to me, and for help with some English language sections my son, Dr. Kamel and his wife Dr. Enes; the two graduated from the University of Illinois at Chicago (UIC). I should also mention the useful work of Mr. Muhammad M. Agha, who has realised a first reading of the text. This book, at least as it is now, would never have seen the light without the fluent, beautiful and advanced scientific English style of my proofreader Mr. Nicholas Hall, who deserves my thanks and appreciation.

I want to thank all these and those I have cited, or one or more of whose maps, figures, photos...etc., I have used, with or without modifications. Thanks a lot to you all.

All support has been offered to me by my wife, Fadia, an educational inspector at Damascus, and my children (Hadi, Mais, Nour and Kamel), who all graduated with high level from French and American universities, after their first level graduation from Damascus University.

My measurements and analyses were done in several universities, centres and laboratories: CRPG of Nancy, France; Free University, Amsterdam (Lab. Prof. J. Touret); in the Laboratories of Profs. Xavier Le Pichon, from Ecole Normale Superieure, Paris; J. Chorowicj and A. Jambon (MAGIE), of the University of Pierre and Marie Curie, Paris. I would like to thank them all alongside their teams for their friendly welcome and their generosity during my sojourn in their laboratories as a visitor professor.

I am currently flying, between Syria, France and the United States, to be with them all, with the past and the present. And I have kept on writing for the future through this time, through Cambridge Scholars Publishing.

INTRODUCTION

Writing a scientific book by a specialist from an Arab country, to be published by a foreign centre such as Cambridge Scholars Publishing, presents several implications. First, the sciences are international, not limited to a single country or nation or religion, or distinguishing between men or women, white or black, strong or weak. They are a universal concern for the service of all humanity. Consequently, I am proud, as a Syrian, to participate with other scientists in making the progress of science a success for all.

Why write a book on the geology of Syria? Because this book concentrates on an important subject, the geology of Syria, which is, from all points of view, an important Middle Eastern Arab country. It is in the centre of the Arab world, which explains the attraction of many experts from all over the word, who have published separate articles on their work. This is especially true of the petroleum companies, which have focused on the commercial discoveries of petroleum more than the basics of geological studies. This in turn reveals the need for a complete book on the different geological aspects of Syria, in their totality.

The high importance of Syria's principal geological aspects derives from the following reasons:

- The country's important geographical and strategic location between the Asiatic Arab countries and that part of the African continent which adjoins it;

- Its geological diversity, the outcrops of which are different geological formations: sedimentary and volcano-magmatic, including the ophiolitic complex with its metamorphic intrusions;

- Its importance for understanding the geodynamics of the regional geology, especially the geology of the Arab and African plates;

- The existence of great and important structures such as the Syrian fault (rift), the continuity of the Dead Sea Fault Zone, the Palmyrides chain, the Euphrates Trough, and others;

- Its wealth in natural resources including hydrocarbons;

- The quantity and quality of published studies.

All these parameters, in addition to my numerous recent studies, have encouraged me to propose and write this book, and present to readers a general synthesis on the geology of Syria in its regional frame. This work consists of three parts; each one is composed of several chapters, as follows:

Part One focuses on general features. It includes four chapters:

Chapter One is a foreword. It discusses the following headlines: localities, definitions, parameters, and concepts. These headlines focus on the studied region, the Tel Thenoun volcano, mantellic xenoliths, fluid inclusions, meteorites, equilibrium and disequilibrium, energy, geothermobarometry, economic feasibility and metasomatism.

Chapter Two expounds the field and laboratory methodologies of many fields including tectonic activity to estimate the displacement rate/year, and analysis methods, such as R4DT, and INVD. The laboratory methods include: geophysics methods using advanced programs; fluid inclusion and geothermobarometry methods, and chemical analysis methodologies.

Chapter Three explains the grand lines of Syrian stratigraphy in its two complementary parts, the surface stratigraphy through the outcrops, and the subsurface using data from wells. The two parts give a complete vision of the litho-stratigraphy, including the principal units, formations and members of the general stratigraphic column.

Chapter Four of this first part focuses on the geodynamic framework and tectonic traits, including the principal tectonic units, and thence the geotectonics scale, using the notion of plate tectonics, then the regional tectonics, arriving at the detailed tectonics of the country.

Part Two presents the studies and research executed by the author, which focus on new and interesting topics and reach to new data and conclusions at the level of their domain. It includes six chapters:

Chapter Five explains the regional seismicity, and that of Syria, in relation to the tectonic features. It also explains estimation of the rate of movement, so as to draw seismic zonation maps, both for Syria and at the level of the Arab Plate.

Chapter Six discusses the volcanology and volcano-magmatic (and ophiolitic) rocks. It explains the different volcanism episodes during geological history, and the occurrence of this volcanism vertically (through time) and laterally (at the surface). It then determines the different petrographic types after their mineralogical and chemical (principal and trace elements) characteristics, using norm diagrams. It finally determines, as best possible, the conditions of their petrology.

Chapter Seven integrates with the preceding one, Chapter Six, and concentrates on the mantellic xenoliths and their fluid inclusions. Those mantellic xenoliths are relics which are brought up to the surface by the volcanism from different lithostratigraphic levels, the crust or the mantle. Those of the mantle are of more interest because they bring significant data from the deeper levels. Their occurrence varies according to several characteristics: the volcanic type, the geographical position, the localisation of the magmatic chamber, and the locality on the surface of the volcanic cone. Also, there is variation in the data obtained from the fluid inclusions in these mantellic xenoliths compared with what would theoretically be expected. Thus, these fluid inclusions offer the basis for a complete theoretical idea, giving an indication of the historic background of the host rocks. In addition, they are used in geothermobarometry to estimate Pressure (P), Temperature (T) and Depth (D) conditions, using the density of the enclosed fluid, usually carbonic fluid, or gas, after the thermodynamic conditions.

Chapter Eight presents the discovery of a rare mineral, the Sapphirine which was found in one sample of the mantellic xenoliths from the Tel Thenoun volcano. So, it is entitled: Sapphirine mineral of Tel Thenoun mantel xenoliths – signification and interpretation.

Part Three is entitled: “Application and natural resources geology of Syria – Damask Saber”. This part includes four chapters:

C**hapter Nine** deals with “the hydrocarbon potential – fluid inclusions applications”. It focuses on the hydrocarbongeology, and emphasizes the petroleum field in Syria, the different formations, with their characteristics: productive, reservoir, or cover formation concluding with the petroleum potential.

Chapter Ten studies the meteorites in Syria, and is titled: “On the meteorites in Syria with a special regard to the Damask Saber”. In this chapter the author presents the results of a specific piece of work, in the

field and in the Syrian museums, throughout five years, with an example on Syrian ancestors' historic knowledge of the meteorites as gained from the Damask Saber.

Chapter Eleven presents a studied case on Djebel Abd El Aziz, entitled: "A new concept on the petroleum potential of the Djebel Abd El Aziz anticline, NE Syria".

Chapter Twelve is entitled: "Remote sensing applications – Examples", which presents the research results, from different areas of Syria, on the management of water resources using remote sensing techniques.

The book reaches its end with a brief epilogue reflecting the global human view of the author, calling for a change for the better; not by wars but by peaceful methods and scientific knowledge, as well as by honest competitiveness. He concludes by asking if this book has achieved its goal, leaving the reader, specialists and higher education students to give their judgement on this point.

PART ONE

GENERAL FEATURES

Chapter One - Foreword: Previous studies, Localities, Definitions, Parameter, and Concepts

Chapter Two - Field and laboratory methodologies

Chapter Three – Stratigraphy – outcrops and well data

Chapter Four - Geodynamic frame and tectonic features – principal tectonic units

CHAPTER ONE

FOREWORD: PREVIOUS STUDIES, LOCALITIES, DEFINITIONS, CONCEPTS, PARAMETERS

Abstract

This chapter represents a foreword to this work. It deals with the previous studies, the studied localities, and the explanation of some expressions (definitions, concepts, and parameters).

The previous studies present a general history of these studies through time and scientifically, from the past to the present.

***Chronologically**, they are classified in four steps: the first one is European, and extends between the end of nineteenth century and the end of Dubertret's role (1886-1966); the second is the Soviet era of Ponikarov and his team (1966-1968); the third is the period of hydrocarbon studies known under the title of "service contracts", which extended from 1965 to 2010, and the fourth is the academic step, which includes the research subjects of the Syrian universities, their theses and publications.*

***Scientifically**, several specialty domains are distinguished: litho-stratigraphy, petrography (sedimentary, magmatic, and complex ophiolitic rocks and metamorphic intrusions), structural and tectonic studies, geophysical studies, hydrology and hydrogeologic studies, and hydrocarbon exploration studies;*

The localities include: the studied region, and areas taken as studied cases, their geographic position and their characteristics;

*The **definitions** are concerned with: mantellic xenoliths, these and those deep rocky stones cut from the mantle and carried up by volcanic magma to the surface, the fluid inclusions included in a gap in the rock minerals, and the meteorites which are fragments that reach to the earth from outer space;*

*The **concepts** are: metasomatism, a phenomenon which implicates replacement of a rock by another one due to two dissolution and formation operations; and energy in geology (metamorphism and seismology), which is a power or capacity (physically) to do work.*

*The **parameters** are: equilibrium and disequilibrium which mean, in the first case, the stability of a rock for a period of time until there is a change of the thermodynamic conditions, where the rock is disequilibrated and new minerals are formed, and consequentially, a new rock is formed.*

*The **geothermobarometry** is the set of parameters which indicate the Pressure, Temperature, and Depth conditions, and the stability parameters of a phase.*

*The **economic feasibility** is the indicator of the possibility of establishing profitable economic projects depending on the expenditures, the profits, and the compound interest.*

For any reader, it is important to explain these key terms, because the author also hopes, in addition to the scientific value, to present a work of knowledge that will stimulate the interest of readers, scientists and educators in two complementary goals, knowledge and education. Furthermore, some scientific specialists need to imagine, during reading, the localisation of the sites studied in this work, and to remember some concepts and notions. The author found it necessary to start with this explanation.

1-1- Previous studies

There have been many studies executed on the geologic features of Syria. For historical and ethical reasons, we will briefly draw the trajectory of these studies, according to their time, from the past to the present, as well as their specialties, their subjects.

1-1-1- Chronological historical studies

We can distinguish these steps: the oldest step, the Soviet step, the step of the service contracts, and the academic step.

A-The oldest step: This step began with the separate studies of some engaged European geologists. The first were by Lartet (1869), with studies on the basaltic lavas and cones in the Arab region, and Doss (1886), who

was interested in the basalt of the Levant fault, and the tuff of Houran. Then came Blankenhorn (1891), with his brief comparison study between the Arab platform and the Alpine zone, and thesis of 1914 on the basaltic rocks. His successor was Finkck (1898) with studies on Latakia-Kuloss fault and its relation with the Arab plate and Taurus zone. They were followed by Kober (1916) with studies on the ophiolitic complex bounded by the Arab plate, and Krenkle (1924) with studies on the formation of the Syrian mountain chains, considered as resulting from the Albian chains and the African movement. But the more detailed studies which distinguish this step in this country and its neighbors began with the works of Dubertret (1929-1966) who, as there were no cars or roads, walked or used donkeys, with his team: some associate students and workers helped to drive him about in the field. Many and various studies were executed by Dubertret and his team: on the volcanic regions of Haouran, Djebel El Arab, and Diret El-Jaboul (1929); also on the basaltic nappes (1933); the ophiolitic complex of green rocks (1953); and most importantly the stratigraphic and structural studies (1932, 1936, 1937). From this work, the first geological map of Syria (at 1/1,000,000 scale) was published (1945), in addition to maps of some other neighboring areas, such as Lebanon and Palestine, at a more detailed scale (1949, 1955). These works are still important to use until the present day, due to their high accuracy, as they were executed in the field by walking or using animals.

B-The Soviet step: The second step, more advanced and largest, which covered the whole area of Syria, with more advanced techniques, was related to the Soviet team, guided by Ponikarov (1966-1968). Complete and various studies that covered the different geologic subjects were achieved: Stratigraphy, lithology, paleogeography, tectonics, hydrology and hydrogeology, hydrocarbonic exploration, geo-engineering, and natural resources. In addition, several geologic maps were established at different scales: (1/1 000 000; 1/500 000; 1/200 000; 1/100 000; 1/50 000).

C-The service contracts step: This step began with Syrian openness towards foreign companies, whereby many companies presented their projects to explore one or more of the sectors drawn up by the Syrian authorities (Fig.1-1). These interested companies signed exploration contracts; then, if a hydrocarbon commercial discovery were realized a productive company would be created, and the production distributed according to agreed-upon proportions. For example, Shell is the contracting company for the exploration, the productive company is Al-Furat; Elf is the French contracting company and Deir Ezzor is the commercial one. In

addition to these hydrocarbon exploration works, the results of many studies were published in scientific journals or stated at international conferences.

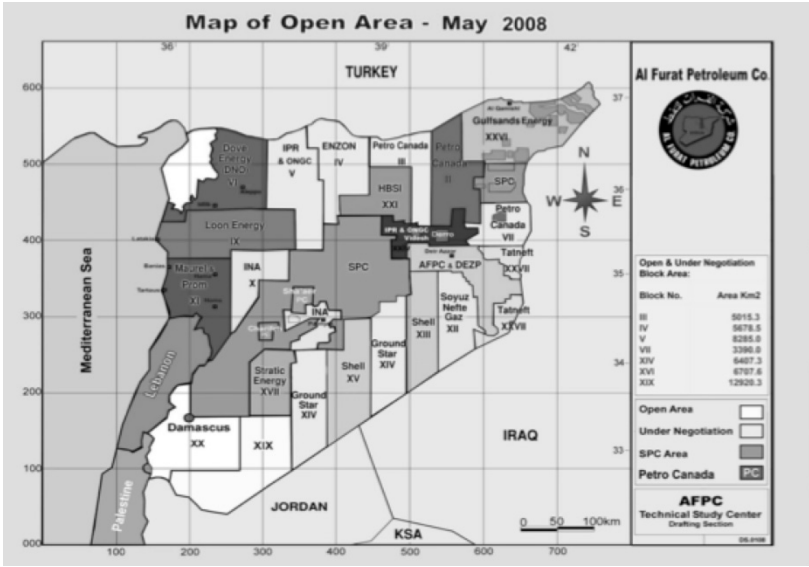

Fig. 1-1- Distribution of open Syrian areas (sector) Map (Al Furat, 2008).

D-Cooperative scientific projects: Parallel to these works, some scientific cooperative projects signed by Syrian companies and universities on the one side, and foreign universities and companies on the other, led to the publication of many scientific articles such as:

- Cornell University (headed by Barazangi) - Syrian Petroleum Company (SPC) in all domains, led to the publication of some papers in various journals: Chaimov et al. (1990, 1993), Best et al. (1991, 1992), Al-Saad et al. (1992), Brew et al. (1997, 1999, 2000, 2001), But these works were still decorative with their colorful figures without any additional data on a different scientific scale;

- Damascus university (headed by Bilal) – GORS (Syria), University of Pierre and Marie Curie, Paris, on the Homs basalt and its active tectonics (Chorowicz et al., 2005);

- Damascus University (headed by Bilal) - Aleppo University - University Saint-Etienne (Ismail et al., 2008, 2019);

- In addition there were some separate studies and publications by Syrian specialists, and studies by the Syrian Petroleum Company (SPC): Khrestin (1993), Mouty (1997a, b), Bilal (2002), Al-Abdallah (2008), and unpublished studies of SPC.

E-The academic studies step: These studies and publications represent the student theses and their publication with their professors (the authors): Sheleh (2000), Kafa (2005, 2018), Badour (2009, 2018), Mansour (2015, 2018), and others such as El Kadi (2009), and El Kadi and Mahfood (2009).

1-1-2- Specialized historical studies

They include the different specialty studies: lithostratigraphy, petrography, tectonics, and geophysics methods and studies.

A-Lithostratigraphic studies: They include base studies for surveys and natural resources geology (mapping, geo-engineering, hydrogeology, ...). The oldest studies date back to Dubertret and his team (1936 – 1969). Then, there were the studies of Ponikarov and his team (1966, 1967, 1968). These were followed by the work of service contracts companies, and the group of Cornell university (headed by Barazangi), during the last ten years of the twentieth century and the beginning of the twenty-first century (1990-2005) (see1-1-1, E).

B- Petrography: This domain includes all the petrographic varieties of rocks, magmatic rocks, and green rocks and their metamorphic intrusions.

- Sedimentary rocks were studied as a helpful part of the lithostratigraphy. They are: clay, Marne, Limestone, sandstones, dolomites and all other types of these rocks.

- Magmatic rocks: they are the volcanic rocks. The oldest studies on these rocks in the region date back to Lartet (1869), then those of Doss (1886), followed by Blankenhorn's studies (1914), and those of Tyrell (1930). But the first and most important and complete studies date back to Dubertret and his team (1929, 1933, 1940, 1954), and those of Ponikarov (1966-1968), Razvalyeav (1965), Krasnov et al. (1966), and Kozolo et al. (1966).

- Green rocks: Syria represents one of the countries associated with the presence of the ophiolitic arc, which includes Turkey, Cyprus, and Oman. The Syrian part of this arc is known under the name of ophiolitic complex. The first who studied this complex were Dubertret and other French geologists, especially Parrot (1974a, b).

- Metamorphic rocks: metamorphic rocks are rare in Syria. They were studied by Dubertret and Ponikarov as a part of the ophiolitic complex, but the first systematic studies date back to: Chenvoy (1959), Piro (1967), and Whitechurch (1974);

- Syrian researchers who were interested in volcanic rocks through their studies include: Otaki (1970), Bilal (1988, 1994, 2016), Bilal and Touret (2001), or through their Master and Doctorate students: Sheleh (1998, 2000), Dawod et al. (2010).

C-Tectonics: The oldest tectonic studies date back to Blankenhorn (1891) through a brief study comparing the Arab platform with the pleated Alpine zone, and to Krenkle (1924), who considered the Syrian mountain chains and their tectonic units formed due to the Alpine movements and that of the African plate towards the north. But the important beginning of more extensive and detailed studies on Syrian and Arab plate were executed by Dubertret (1936-1966), with the publication of the first geological map of 1/1 000 000, followed by Ponikarov (1966-1967). Tectonically, Syria takes a distinguished place on the stable and unstable parts of the Arab plate, with the most important structures being the coastal chain, the Palmyrides, and most of all the Syrian rift (Fig.1-2).

These studies obtained important data on: the base depth under Syria; the results of seismic profiles; the magnetism and Bouguer anomalies; the results of explorative drilling; the general tectonics. Different models for the tectonic units were proposed, the most important being: The Ponikarov model (1966), which distinguishes between two zones, one internal (stable) and the other external (unstable) (Bilal, 2013); the Brew et al. model (2001), which distinguishes between four zones: Palmyrides, the Euphrates, Abd El Aziz-Sinjar zone, and Dead Sea Fault Zone; and the most recent one, the SPC model, (2011, Fig.1-3).

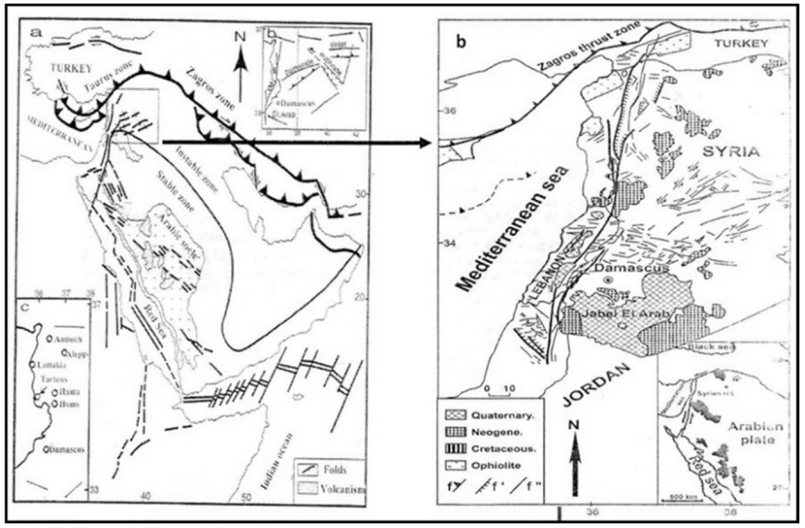

Fig. 1-2- Distribution of two stable and unstable zones of the Arab plate (Ott d'Estevou et al., 1987, modified Bilal, 2000), and the overall structure of the Dead Sea Fault Zone (DSFZ) (Bilal and Touret, 2001).

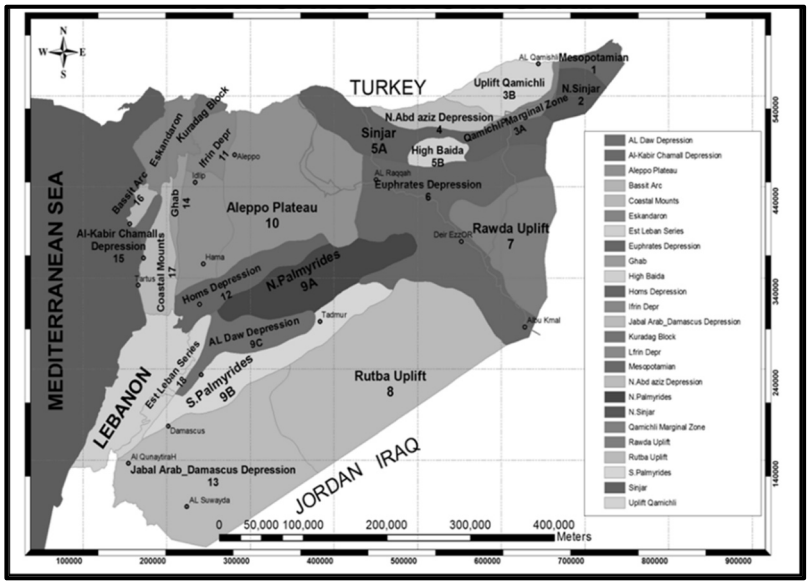

Fig. 1-3- Map of tectonic units of Syria (SPC, 2011).

D-Geophysics methods and studies: For exploring the geological structure of Syria different geophysics methods were used: magnetic, gravitational, and seismic surveys.

The magnetic survey was first used by the American Carnegie Institute (1922-1928), the French (F. A. Geographical service), and French Meteorologic service (1923-1939), with distances of 20-25 km between the observation points. These were part of the international magnetic map at scales 1/200 000, and 1/500 000 with distances of 0.51m gal, and 1m gal respectively. Thereby, a magnetic map of Syria was established by the Syrian Petroleum Company (SPC 1982, Fig.1-4).

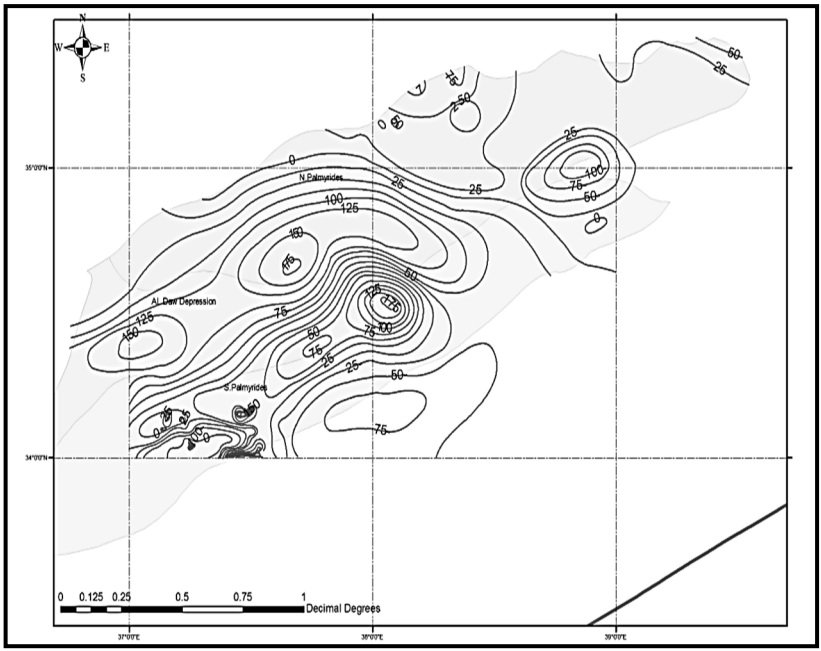

Fig. 1-4- Syrian map of magnetic survey (SPC, 1982).

The gravitational survey begun by Techno Export Co., where two Bouguer abnormalities maps were established (scales 1/200 000, 1/500 000, 1964). Then in 1975 the French Petroleum Institute (IFP) established the Bouguer anomalies maps of 1/200 000,1/500 000 with a distance of 2m gal, Fig 1-5.

The seismic survey started late with the help of Russian experts in (1964-1966). Then there were the seismic surveys by the French (C.G.G) company (1964-1967) and the Algerian Company (1968-1970); but the most important step was with the Techno Export. Co. (1972-1973), whose surveys were completed by the SPC since 1978, with intensive survey works (Fig.1-6), using 2nd and 3rd methods.

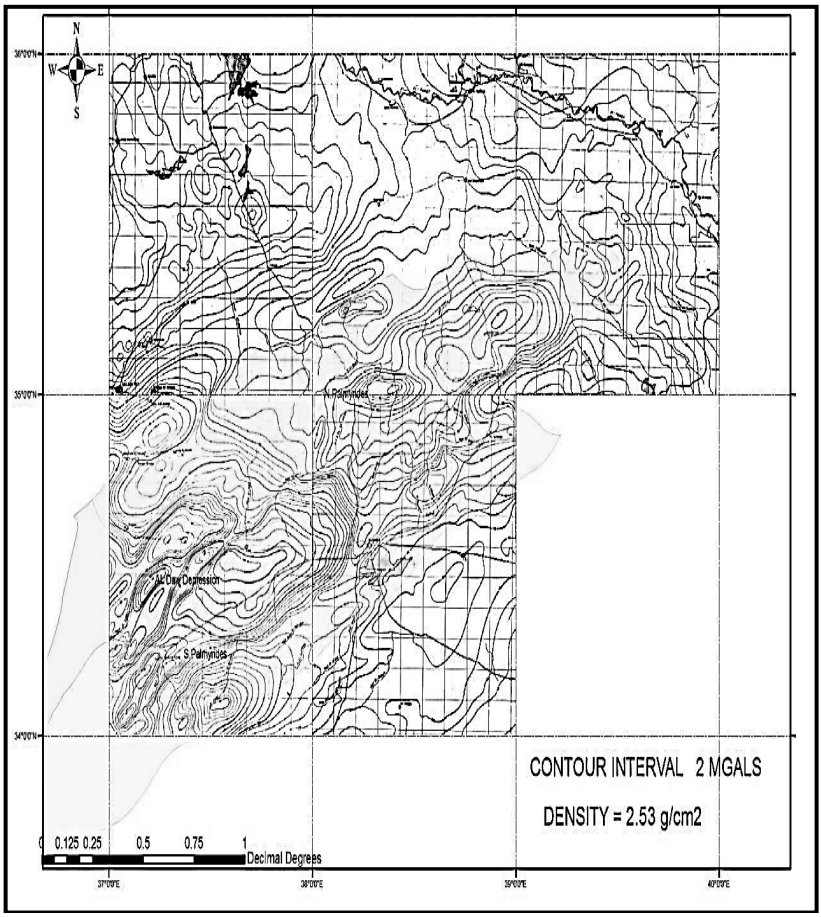

Fig. 1-5- Syrian map of gravitational survey (SPC, 1974).