Pakistan Journal of Applied Sciences 3 (4): 216-224, 2003
ISSN 1607-8926

A New Evidence for Lateral Displacement along Wadi Araba Fault/the Dead Sea Transform, Jordan

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ABSTRACT

The Dead Sea rift represents the northern part of the African Arabian rift system. A sinistral strike-slip motion along the Dead Sea rift is confirmed by the continuity in the restored trend of the structural elements. Numerous researchers discussed the structural and lithological evidence for that movement before. Hatcher *et al.* (1981) first discussed the geophysical evidences. In this study new evidence based on uranium mineralization along with a detailed gravity survey, carried out in the last decade in Dana and Timna areas is used to emphasize the strike-slip movement.

Key wrods:

INTRODUCTION

Wadi Araba is situated between the Gulf of Aqaba basin in the south and the Dead Sea basin in the north (Fig. 1) along the Dead Sea rift (DSR). The DSR is one of the most impressive geomorphologic phenomenons on the earth surfaces. Geologically, the DSR started to form as a rift valley about 25 million years ago (during the Miocene, Burdon and 1959, Bender, 1968). Originally before Miocene the geologic formations were continuous on both sides of the rift valley. During the formation of the DSR, the eastern rim was upthrown relative to the western rim, and consequently older rocks of the basement complex and volcanics became exposed at the eastern block escarpment foothills (Bender 1968).

Tectonic and Structural Setting

Tectonically, the DSR represents the middle part of a giant tectonic element extending from the Red Sea spreading in the south to the collisional belt of southern Turkey (Fig.1). The tectonic elements comprise three major deformational events, namely, the Syrian Arch fold, the Shear belt zone (Erytherean fault system) and the transform fault of Levant phase (Freund *et al.*, 1970 and Garfunkel, 1970). From the point of view of plate tectonics this transform fault represents the continental plate boundary zone, which separates the Arabian plate from the African plate (Dubertret, 1932; Quennell, 1958 and Garfunkel, 1970, 1981). Dubertret (1932), Willings (1938) and Burdon (1959) first pointed out the evidence of a transform structure of the Dead Sea Rift. According to these authors, the facial formation of the Cambrian, the Triassic and the Jurassic sediment on both sides of the rift valley is correlated only after assuming a horizontal dislocation towards the north for the Arabian plate (transjordanian block). Quennell (1958) added, that this dislocation along the sinistral strike slip fault is 107 Km. Freund (1968) reported that the Arabian plate (transjordanian, block) is dislocated only between 70-80 Km depending on facial studies of different formations. Bandel (1981) comparing geological logs of wells and profiles of outcrops especially those of Triassic and Jurassic rocks concluded that the strike slip motion of about 107 km. Wetzel and Morton (1959) concluded that the Araba Jordan Valley rift has been subsiding since Cretaceous time. Bender (1968) confirmed this result. Mart and Horowitz (1981) suggested that during the shear belt (Erythrean) phase, in the Dead Sea rift E-W and NW-SE trending fault were formed, while during the Levant phase the Dead Sea basin and the faulting of very limited displacement along the Dead Sea rift took place.

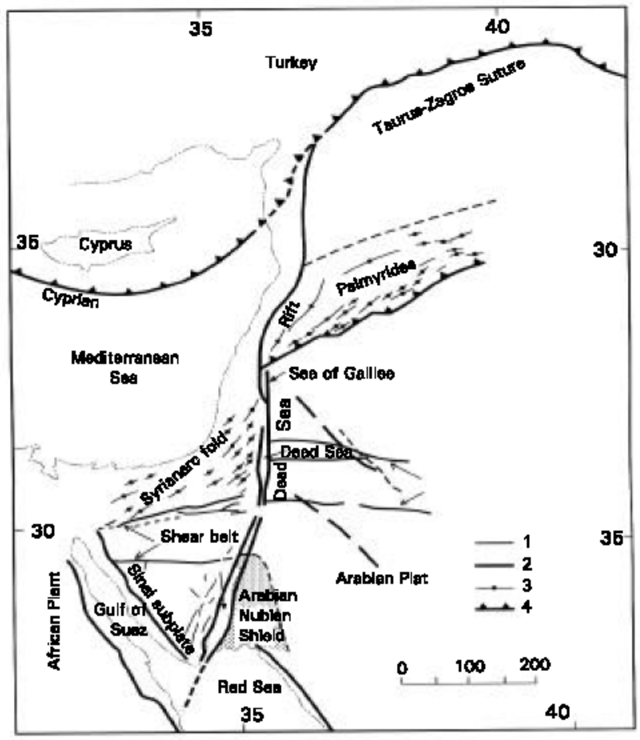

Fig. 1: Generalized tectonic steeing of the Middle East, showing the Arabian Plate, African Plate, Sinal Subplate, the Dead Sea Transform (Including Gulf of Aqaba, Dead Sea and Sea of Galilee), Syrian Arch, Palmyrides Zone, Shear Blt and Taurus-Zagros Suture. 1-Faults; 2-Main Faults; 3-Fold Axes; 4- Main Thrust Fronts (modified after Ben-Avraham and Grassc, 1991; Bender, 1974)

Recent studies of Segev *et al.* (1999) based on geophysical measurements in Timna Valley (22 km to the north of the Gulf of Aqaba) confirm a sinistral strike-slip of 105 km as reported by Burdon (1959); Freund *et al.* (1970); Garfunkel (1981), Hatcher *et al.* (1981) and Rybakov *et al.* (1996).

The excellent exposure of the crystalline basement in the Timna Valley (south of Israel) and Wadi Dana in Jordan (Geological map of the Dead Sea Rift along Wadi Araba, scale 1: 250000, prepared by the joint Israeli-Jordanian team, Sneh *et al.* 1998) makes these areas suitable for different kind of studies to shed light on the left-lateral displacement along Wadi Araba.

Study Area

Wadi Dana area lies at about 127 km to the north of the Gulf of Aqaba at the eastern side of the Dead Sea transform fault (Fig.2). The area is built of Proterozoic Fidan granite of the Araba Complex, unconformably overlain by Salib Arkose Formation with pebble-cobble conglomerate at the base (Early Cambrian). This is followed by Burj Dolomite Shale Formation (Late Early-Middle Cambrian), which in turn is overlain by Um Ishrin Sandstone Formation of Middle-Late Cambrian, age (Barjous, 1987).

Two major faults characterize the area, namely the Dana fault to the north and the Salawan fault to the south. Apparently both faults truncate at each other in the west. Dana horst block, which consists of Precambrian quartz porphyry and granites, is sandwiched from three sides by Cambrian sandstones, the contact of which are the above mentioned faults (Bender, 1974).

The Timna Valley lies at about 22 km to the north of the Gulf of Aqaba at the western side of the Dead Sea transform fault (Fig.2). Geomorphologically, the Timna massif is similar to Dana horst, which is a raised core, surrounded by Cambrian sandstones with contacts to the surrounding consisting of multidirectional faults (Segev *et al.*, 1999). The Timna area forms an erosional circular dome of Precambrian basement intrusive comprising mafic to felsic plutonites rocks cut by a swarm of dykes. The Timna dome has been shared along its diameter by the

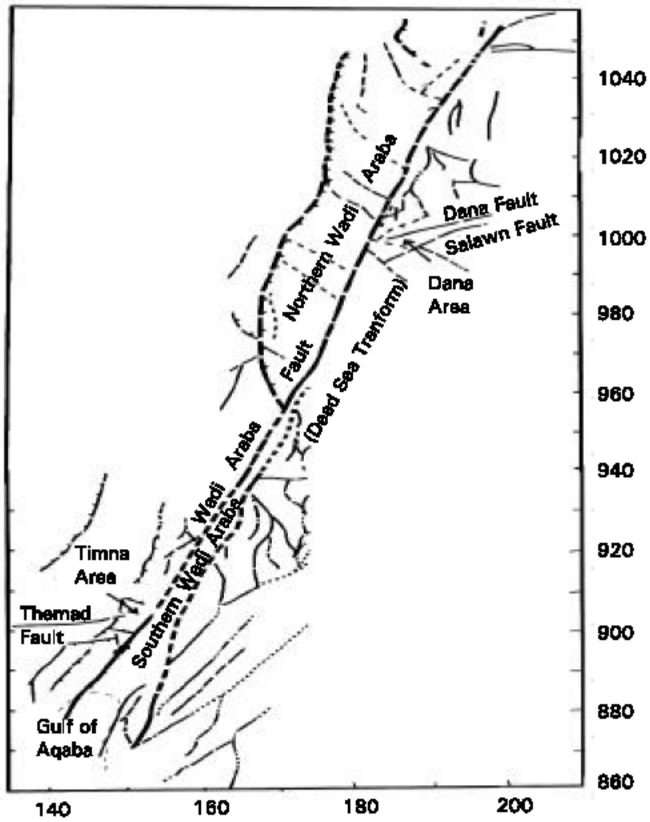

Fig. 2: General Tectonic Structure of Wadi Araba. The Major Faults (Wadi Araba, Themad, Salwan and Dana) and the location of Dana and Timna Areas Are shown (Modified after Sneh et al., 1998, Bender, 1974 and Barjous, 1987). Coordinates are in cassini Palestine Grid

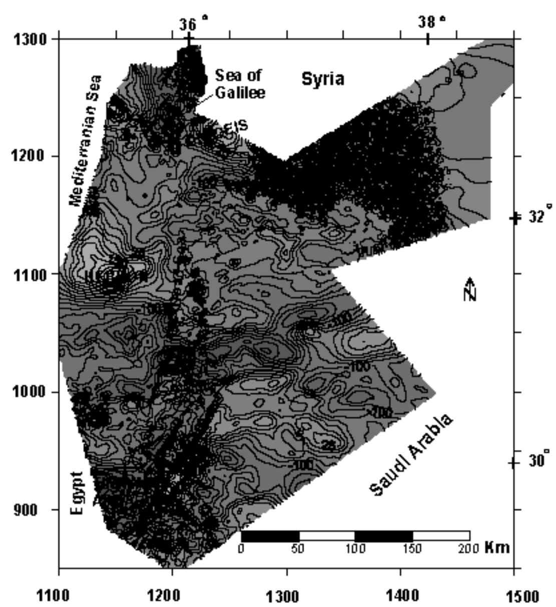

Fig. 3: Magnetic Anomaly Map of Jordan and Israel. Contour Interval is 25 nT. The Aeromagnetic data along the Dead Sea Rift were combined in joint magnetic data base of Jordan and Israel that was estabilihed by the natural resources authority of Jordan and the Geophysical institute of Israel (Rybakov, Al-Zoubi and Hassouneh, 1999).

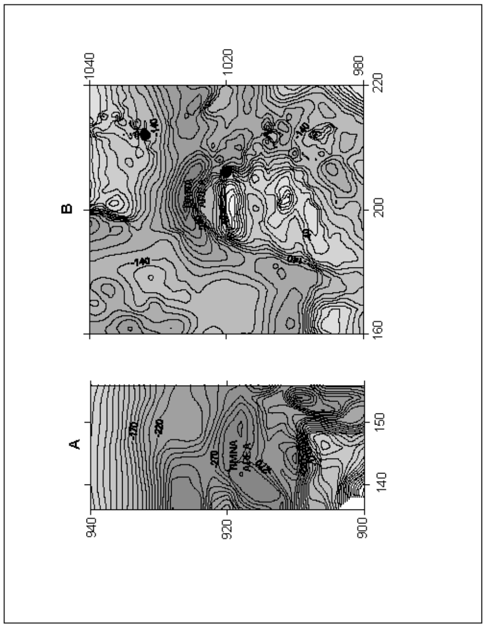

Fig. 4: Magnetic anomaly Map. A- Timna Area; B-Dana Area (Modified After Hatcher El., 1981). Contour in nT). Coordinates are in Cassini Palestine Girld

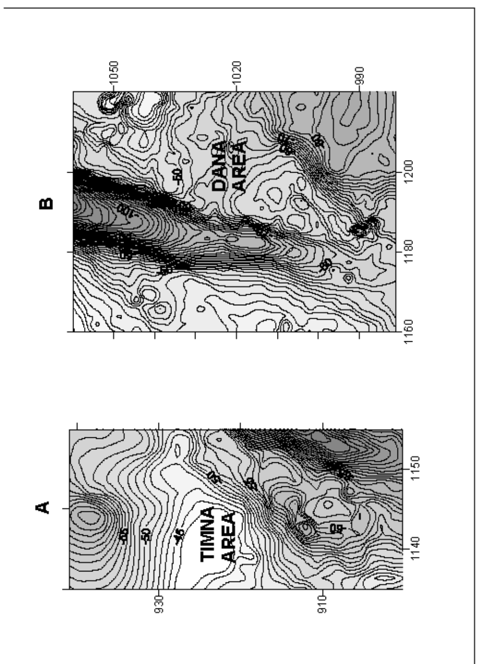

Fig. 5: Bouguer Gravity Anomaly Map of Timna Area (A, after Ten-Brink *et al.*, 2002) and Dana Area (B). Contour in Mgal. Coordinates are in Cassini Palestine Grid

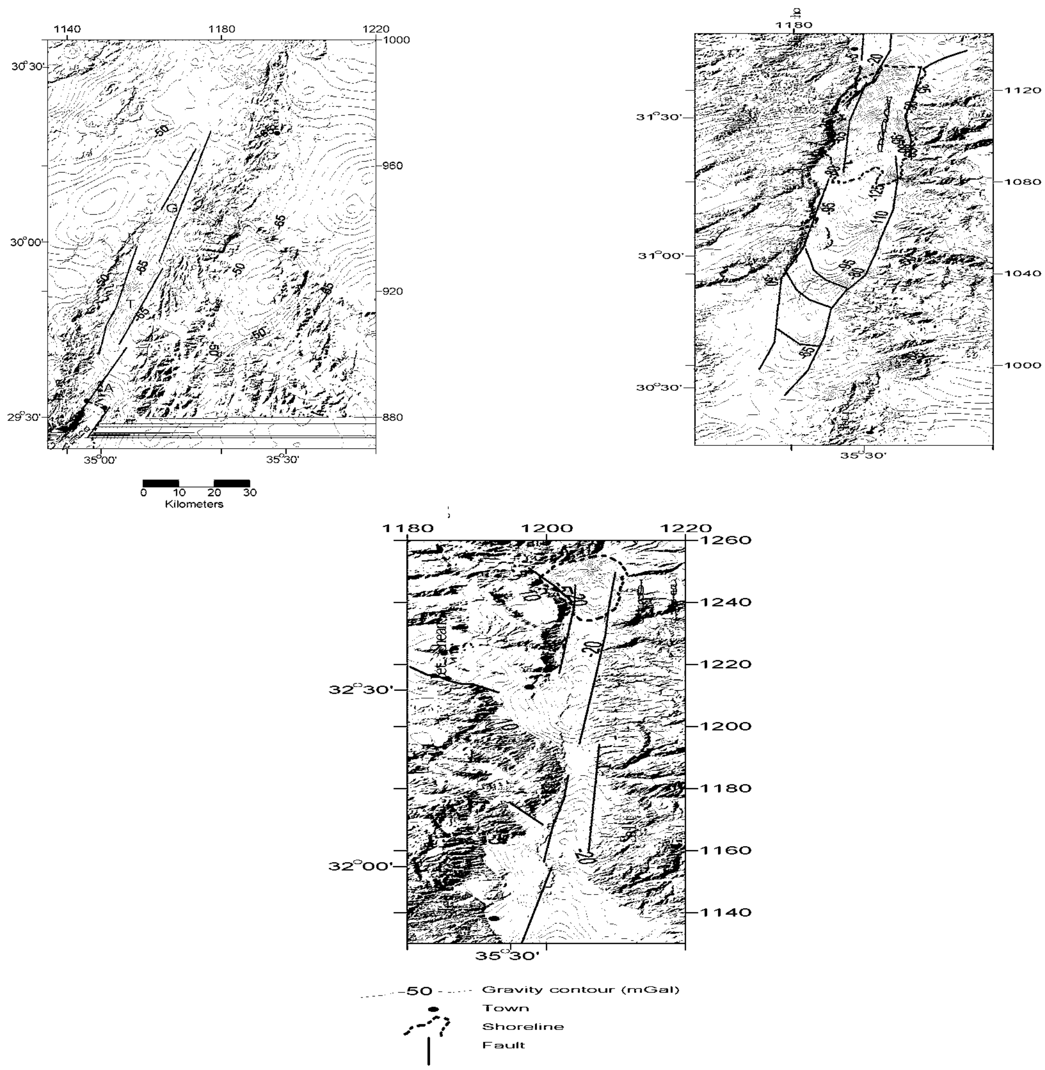

Fig. 6: Bouguer Gravity Anomly Map of the Dead Sea Transform, Jordan and Isreal, Contour in Mgal. Background: Shaded Relief Topography from Digital Terrain Model (Hall, 1993). Showing Wadi Araba Basins A-Aqaba (Elat); G-Gharandel and Timna-Qa-Taba (after ten-Brink *et al.*, 2002)

western border fault of the Dead Sea transform (Segev *et al.*, 1999). Lower Paleozoic to Lower Cretaceous rock ` formations overlies the basement complex. The lower part comprises arkosic sandstones of Amudei Formation with pebble-cobble conglomerates at the base. The formation is followed by the Timna Formation of lower Cambrian age (Beyth *et al.*, 1994).

Evidence of a Strik-slip Motion along Wadi Araba Fault /Dead Sea Transform

Stratigraphic and tectonic evidence A comparison between the geologic formations and tectonics setting of both wadi Dana and Timna areas (Fig. 2) shows that the lithology, thicknesses, rock types, ages and mineral types are realty of excellent correlation (See geological map of the Dead Sea Rift along Wadi Araba, Jordan and Israel, Sneh, *et al.*, 1998). The sedimentary sequences in both areas overlie the magmatic rocks of the basement complex of Precambrian age (Segev *et al.*, 1999; Barjous, 1987). The Fidan granite in Wadi Dana, which crops out

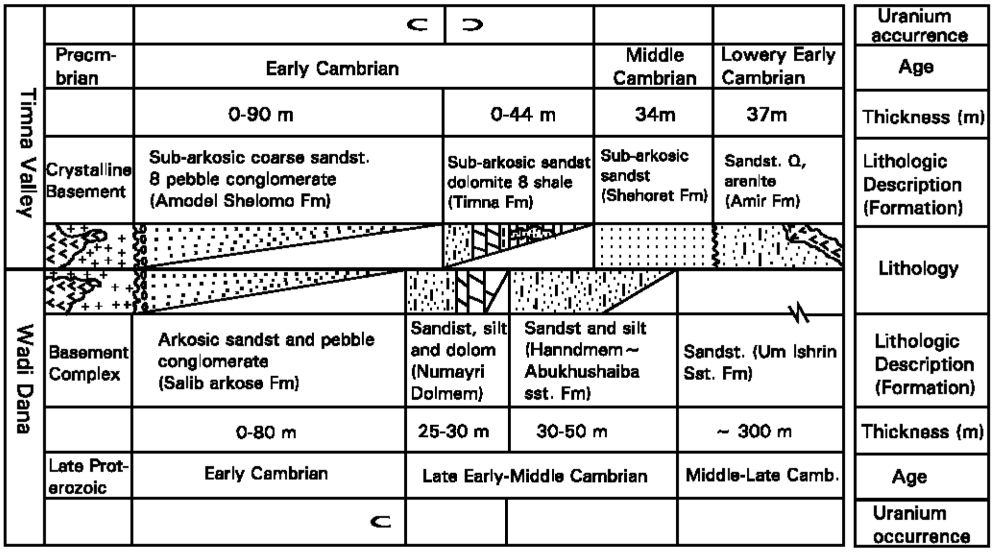

Fig. 7: Correlation of Geologcial formation and Uranium Occurrence Between Dana and Timna Areas. Lithology of timna Area by Segev *et al.*, 1999; Uranium occurrence of Timna by Ayalon, 1985. Lithology of Dana Area by Darjous, 1987; Uranium occurrence of Dana partly by El-Noor, 1994.

along the Wadi, comprises red syenogranite with aplitic granitic dykes intruding the adjacent volcanic suit (Barjous, 1987). On the other side equivalent Timna granite consists also of dark red syenite and syenite porphyry and pink unicrogranite intrusions of aplitic texture (Beyth *et al.*, 1996). The paleotopography of the basement in both areas is overlain by arkosic sandstone (Early Cambrian) of fluviatile origin, with pebble-cobble conglomerates forming the basal part of the sandstone unit. This unit is overlain by arkosic sandstone, silt, dolomite and shale of lagoonal to marine origin of Early Cambrian age. This unit is followed upwards by sandstones of different origins and ages. Basaltic intrusions of Miocene to recent ages are known from the eastern extension of Dana and Salawan faults, which trend approximately parallel to Wadi Dana (Bender, 1968 and Barjous, 1987). Such basalts are also known from Timna area (Bentor, 1985 and Segev *et al.*, 1999). In the southwestern part of Jordan such basalts are very scarce.

The aforementioned evidence confirms the postulation of Dubertret (1932); Willings (1938) and others, that the Arabian (Transjordanian block) plate has been dislocated by 107 km towards the north.

The following tectonic evidence suggest that Dana and Salwan faults represents the eastward extension of Thamed fault (Fig. 2) in African (Sinai- Palestinian block):

1. The Thamed fault, according to Garfunkel (1970) and Segev *et al.*, (1999) is rejuvenated Precambrian fault, which southern edge increases in calcalkaline and alkaline volcanics and granites are observed. The same is observed at the southern edges of Dana and Salwan faults, which consist of an assembly of three magmatic rock formations, namely; Hunyk porphyry granite, Fidan syenogranite and Ahaymir volcanics, quarts feldspar porphyries (Barjous, 1987). Dykes, mostly of E-W strike both structural features. These dykes consist of quartz porphyry at Timna area and of aplite granite at Dana.

2. According to Bartov (1994) and Mart and Horowitz (1981) the E-W extending Thamed fault is dextral strike-slip fault which extends for about 250 km from the Gulf of Suez till the rift valley. Similar to that, the Salwan fault (Barjous, 1988) is also an E-W trending fault with a downthrown southern block by about 900 m and a few kilometers of dextral strike-slip movement as evidenced from the vertical and horizontal drags and horizontal slickenside along the fault. In the Timna area the E-W a dextral shift of the Thamed fault was estimated at 2.5

km (Bentor, 1974), where, both, the Dana and Salwan faults indicate E-W dextral shift of 2.5- 3 km (measured on the geological map of 1: 50,000, Barjous, 1987). On the other hand Dana fault is downthrown to the north. The Dana and Salwan faults formed a horst in between them, which could be correlated with Timna dome. Precambrian and younger faults of N-S, NW-SE and NE-SW directions, form an orthogonal network of faults truncating both structures. The eastern part of the Timna dome seems to be terminated by the Dead Sea rift (Mart *et al.*, 1981). Considering the aforementioned evidence the eastern part of the truncated structure (Timna dome) is most probably represented by Dana horst block.

Geophysical Evidences

The regional airomagnetic survey carried out in Jordan (Hatcher *et al.*, 1981) shows that the elongated E-W trending magnetic anomaly extends for hundreds of kilometers in Sinai and crosses the Dead Sea-Jordan rift valley with its eastern extension in Wadi Dana. This result was confirmed by geophysical studies performed by Segev *et al.* (1999). The detailed magnetic survey in Dana (Fig. 4, B) shows an essentially more complex pattern of the Dana anomaly. The Dana anomaly includes local conjugated positive and negative magnetic anomalies with different strikes and magnitudes. The reason of positive and negative anomalies could be the normal magnetization and the shape of the causative body. Practically the same situation registered by the results of the detailed geophysical survey carried out in Timna area (Fig. 4, A; Segev *et al.*, 1999). There is also a relatively high magnetic anomaly located in the northwestern part of Jordan (Um Qeis), which finds its continuation to the south (Hebron) in the western side of the Dead Sea rift (Fig. 3).

The results of the gravity survey carried out by the Natural Resources Authority in Wadi Araba shows that the Bouguer gravity values in Dana area (Fig. 5, B) range from -50 mGal to -60 mGal (Al-Zoubi, 1998 and tem-Brink *et al.*, 2002), where as this value in Timna area ranges from -48 mGal to -80 mGal (ten-Brink *et al.*, 2002 and Segev *et al.*, 1999). The Bouguer gravity map of Wadi Araba (Fig. 6) shows relatively large negative anomalies (maximum of -70 mGal. These anomalies represent three sedimentary basins (Aqaba-Elat, Timna-Qa-Taba and Gharandal) filled by low-density recent sediments of about 1500 m in thickness. The map (Fig. 6) shows that Wadi Araba basins become narrower and shallower to the north. Several small anomalies (relatively positive) were found along Wadi Araba. The positive gravity anomaly within the Dana area (Fig. 5, B) is believed to be caused by the high structure block located between Salwan fault to the south and Dana fault to the north. The same positive anomaly was found in Timna structure (Fig. 5, A; Segev *et al.*, 1999).

Considering the aforementioned results, the applied geophysical techniques provide the clear evidence for the strike-slip motion along the Dead Sea transform fault.

Mineralization Evidences

Copper and manganese mineralizations are known to occur in different levels of Timna Formation (Ilani, *et al.*, 1987). They were mined in Early Bronze and Roman ages in the eastern and western sides of the rift valley (Abu Ajamieh *et al.*, 1988). Uranium mineralization of Timna area was reported by Ayalon (1985), where as such mineralization in Dana area was first reported by El-Noor, (1994).

According to Ayalon (1985) the most significant uranium occurrences in Timna valley area are associated with Lower Cambrian and consist of black white- mottled line to grite sandstone of 0-25 m in thickness (Nehushtan member) and Mikhort member, which consist of greenish reddish shales of about 3 m in thickness (Fig. 7).

Uranium occurrences of these members comprise lenses of 0.5 to 3.0-m in thickness and up to 50 m in length. The uranium concentration in this area reached in some places several thousand ppm. The uranium mineralization was found to be mostly associated with phosphates and manganese ores.

The radiometry survey in Dana area in Jordan was carried out only in a reconnaissance stage and covered limited areas (El-Noor, personal communication). Two uranium occurrences were identified close to the Dana fault. The uranium mineralization was found to be associated with the Fraible reddish-brownish silts and sandstone (the concentration ranges from 307 ppm to 330 ppm), the Breciated black rock contains manganese and other minerals (the concentration lies between 519 and 625 ppm) and the friable dolomitic rocks show a uranium content of more than 304 ppm and less than 415 ppm.

According to the petrology study carried out by Natural Resources Authority (Tarawneh, personal communication) the uranium mineralization bearing rock forms the base of the Burj Formation (Late Early-Middle Cambrian) and is closely associated with phosphatic materials.

As results of the comparison between the uranium mineralization in Dana and Timna areas the high concentration of uranium is found to be associated with phosphatic lenses and manganese ores, which intercalate Early Cambrian marine sediments (Fig. 7). From the palaeogeographic point of view this marine facies found in the southern part of Jordan is restricted to the northern part of Wadi Araba (Bender, 1968), where as the southern part of Wadi Araba represents deposition of clastic sediments of continental origin. The lack of thorium in the sediment material in both areas (Timna and Dana) is another evidence of marine origin of uranium mineralization. The aforementioned evidence is an indication to explain why uranium-bearing sediments of Timna area were not deposited on the opposite side of the Dead Sea rift.

The results of the detailed geophysical survey (gravity, magnetic) carried out in Dana area at the eastern side of the Dead Sea transform compared with the results of the previous geological and geophysical studies in Timna area in the western side of the Dead Sea transform support the assumption of sinistral strike-slip motion of about 107 km along the Dead Sea transform, reached at before by Dubertret (1932), Quennell (1959), Freuned *et al.*, (1968), Hatcher *et al.* (1981), Sneh (1996) and others. The results of the radiometry survey in Dana shows that uranium mineralization found in Dana and Timan are another evidence that supporting the above-mentioned assumption.

ACKNOWLEDGMENTS

The authors wish to thank the Natural Resources Authority for providing data from their archives. The authors also thank Dr. El-Noor for his comments and valuable suggestions. Dr. Tarawneh comments are also much appreciated.

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