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ROLE OF THE STRUCTURAL UNITS OF AHWAZ ANTICLINE IN CREATING GEOLOGICAL HAZARDS AT THE URBAN RAILWAY NET, IRAN

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Key words: Ahwaz anticline, Urban railway, Wedge failure, Liquefaction, Earthquake, Iran

ABSTRACT

The Ahwaz urban railway tunnel, which is at the stage of construction, is located within the area of Ahwaz anticline and the associated reverse fault. The geological hazards during drilling line 1 tunnel may include variable adhesion between the rotating cutting head shield of the TBM, variable inhomogeneity at the rotating head, planer and wedge failure on the tunnel's roof and sides in addition to the geometric effects of the different joint sets. These effects are studied using Unwedge 3.0 and Dips software. The occurrence of earthquakes on Ahwaz fault would create liquefaction hazard in the saturated sand soils of the fault footwall at the central and southwestern parts of the urban railway.

دور الوحدات التركيبيه لطية الاحواز في نشوء المخاطر الجيولوجيه في شبكة السكك الحديدية، ايران

ابراهيم أحمد محمد

المستخلص

يقع الخط الاول من شبكه المترو لمدينة الاهواز الذى هو قيد الإنشاء فى منطقه طية الأحواز والصدع الموجود فيها. هناك مخاطر جيولوجيه قد تنشأ نتيجه للتغييرات الموجوده فى اتجاهات المضرب والميل للطبقات الصخريه الطينيه الرخوه والطبقات الرمليه الصلبه حيث ان الزياده او النقصان فى كل من مساحه سطح الالتصاق بين الصخور الطينيه وجدار الحفاره و مساحه بروز هذه الطبقات فى مقطع النفق يؤدي الى الدوران غير المتجانس لرأس الحفاره وكذلك ان وجود العديد من الفواصل الصخريه فى القسم المهشم من الصخور الواقع فى منطقه الصدع يؤدي الى انهيار قطع من الصخور من سقف النفق او من جدرانه حيث ان هذه الفواصل تساعد علي الانزلاق الاسفيني و المستوى لهذه القطع وقد تم دراسه هذه المخاطر الجيولوجيه بالاستعانه ببرامج دبس و انويدج. ان وقوع الزلازل فى صدع الاهواز يؤدي الى حدوث ظاهره ميعان التربه الرمليه المشبعه بالماء في القسم الجنوبي الغربي من نفق الخط الاول لشبكه المترو.

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INTRODUCTION

The area of study is located between 48° 35' 00" to 48° 50' 00" E and 31° 13' 00" to 31° 24 00″ N within the Zagros Belt (Figs.1 and 2). The changing in geometrical properties of structural elements of Ahwaz anticline such as strike and dip of layers and also joint surfaces recorded by the author will decrease or increase the clogging risk, inhomogeneity and failures. The crushed rocks of Ahwaz fault zone have a potential of deformation enable of creating geological hazards especially during earthquakes.

The results of geotechnical exploration have been collected and correlated by the author to determine the exact locations of points at which the Ahwaz fault intersects the tunnels of the urban railway network. The aim of the present study is to use the geological and geotechnical analyses to estimate the vulnerability of the railway tunnel during drilling and during the possible occurrence of earthquakes.

The Ahwaz anticline is described by Moteey (1993). It is located at the northern zone of Dezful Embayment (McQuarie 2004). Details on Tunnel Boring Machines are obtained from Ramoni and Anagnoston (2010).

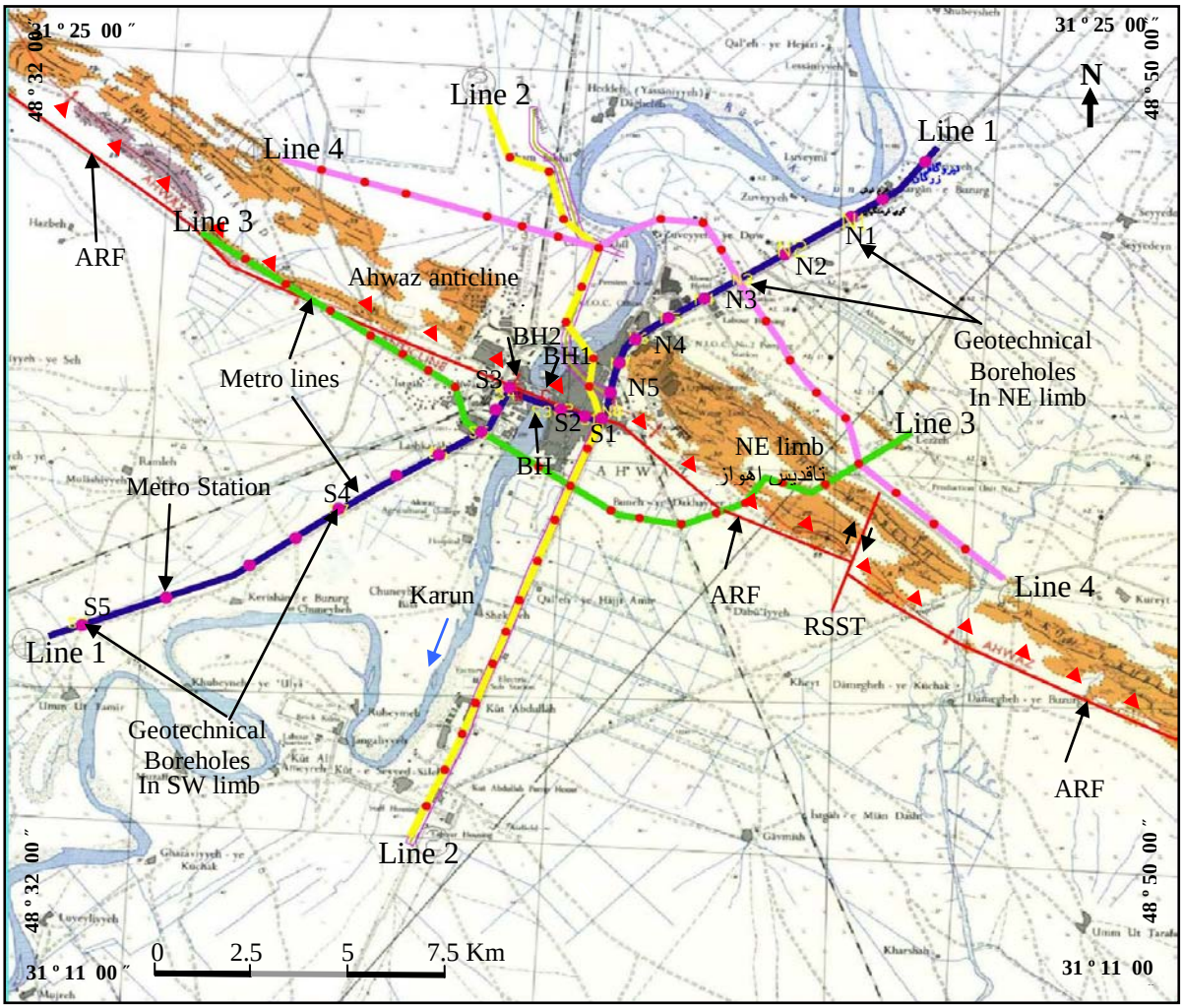

Fig.1: Location of Metro Lines at the area of Ahwaz anticline and Ahwaz reverse fault
ARF: Ahwaz Reverse Fault, RSST: Resalat Strike Slip Fault
(Adapted from Geological Map Sheet NO. 20829E, Scale 1: 100 000 IOOC)

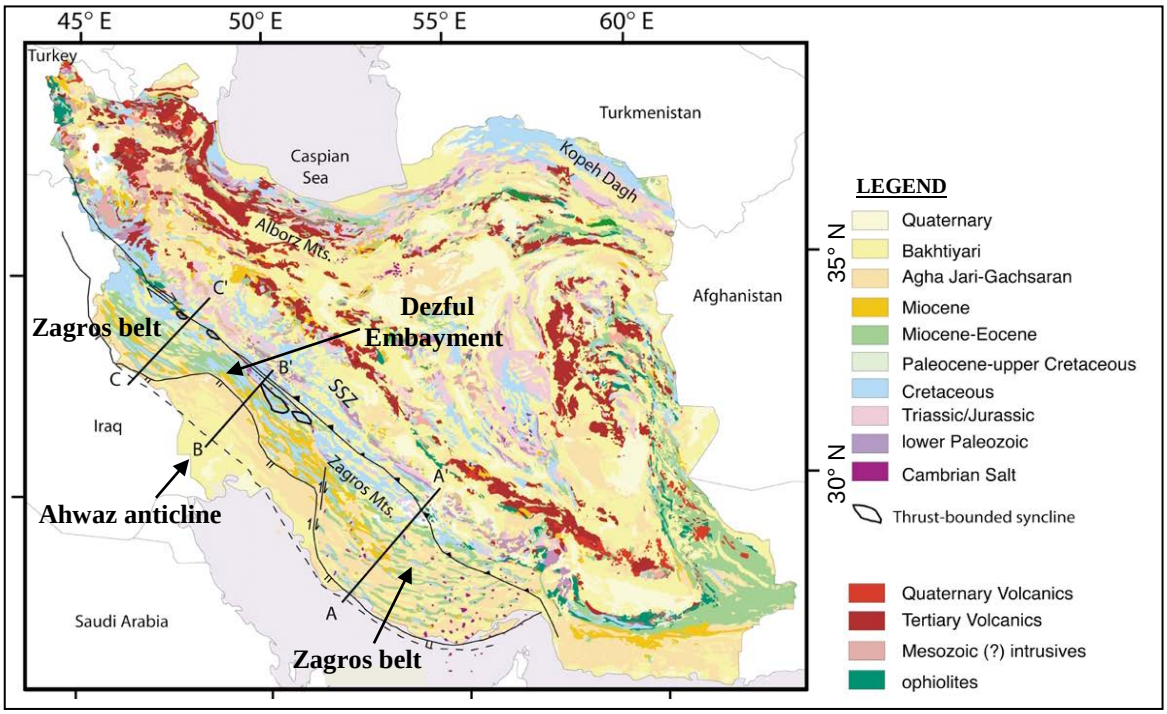

Fig.2: Ahwaz anticline location in the Zagros Fold – Thrust Belt Zone (McQuarrie, 2004)

GEOLOGICAL LOCATION

The Ahwaz anticline is formed of interbedding of sandstone and claystone layers of Upper Miocene to Pliocene age of the Agha Jari Formation (Moteey, 1993). This anticline is located at the front deformation of Zagros Fold-Thrust Belt and at the northern zone of Dezful Embayment (McQuarie, 2004) which is the last cropping anticline of Zagros belt (Fig.2).

The Ahwaz anticline in the vicinity of the Ahwaz urban railway network area is expressed in the form of elongated hills which have an elevation between 40 to 70 meters above sea level. This type of geomorphology is an effect of Ahwaz reverse fault action. Therefore, only the northeastern limb has been recognized to outcrop in these hills (Fig.3). The fault's hanging wall was formed by this limb. The SW limb, on the other hand, has no outcrop except in some limited locations in the form of highly dipping layers (70° to 85°) overturned towards the NE or dip towards the SW and have a low elevation of few meters with respect to the adjacent surroundings (Figs.4 and 5).

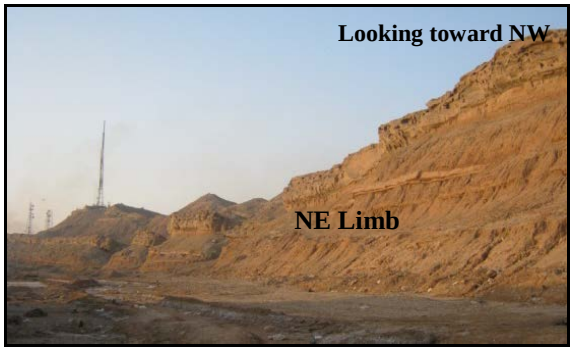

Fig.3: NE limb of Ahwaz anticline (Haseer abad)

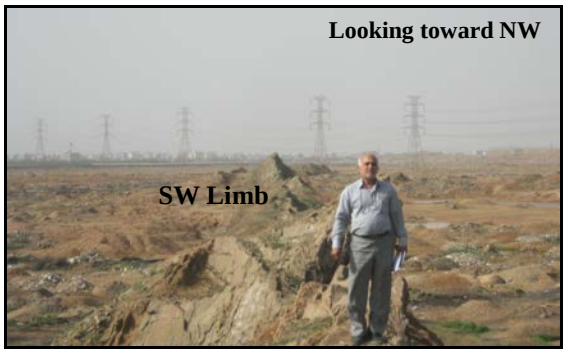

Fig.4: SW limb of Ahwaz anticline (Steel Factory)

Fig.5: SW limb of Ahwaz anticline (Kureyt)

- **Structural Elements of Ahwaz Anticline**

By recording the geometrical properties of the two limbs of Ahwaz anticline, it is found that the anticline is overturned and has an axial plane of 49° to 68° degrees dip towards NE and the trend of its axis is N61W, plunging 2° toward NW (Fig.6A). The angle between the two limbs is about 92° which is classified as an open fold (Fig.6A). The SW limb in some locations is overturned towards the NE (Fig.6B).

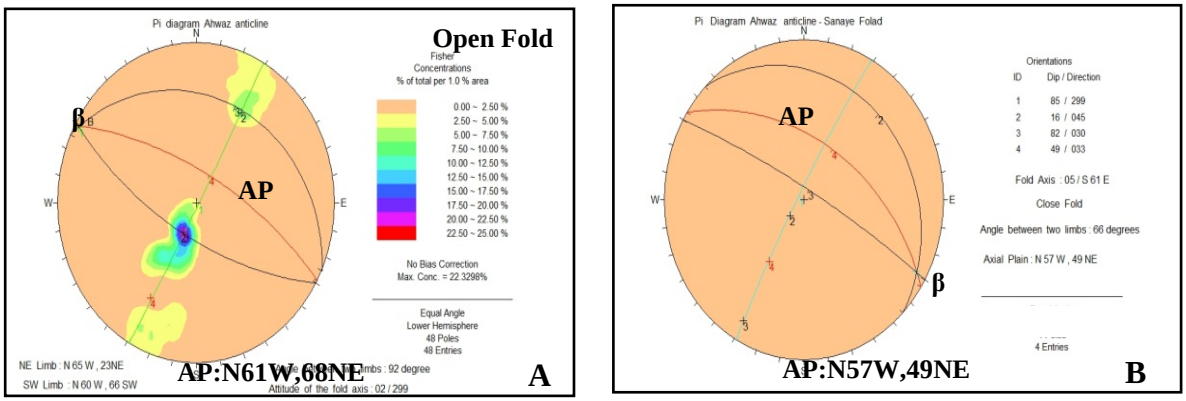

Fig.6: Stereographic projections of π diagram for Ahwaz anticline (A). Overturning of SW limb (B) at the area of Steel Factory of Ahwaz

- **Ahwaz Reverse Fault**

In order to accurately determine the location of the Ahwaz Reverse Fault and its intersection with the tunnels of the urban railway network, field and geotechnical evidences have been used as follows:

– **Field evidence:** There are many evidences indicating a fault in the southwestern limb of Ahwaz anticline. These evidences are sudden discontinuation of Ahwaz anticlinal structure, existence of rock fault in the form of cataclastic rocks (Fig.7), slickenside of fault plane (Fig.8), crushing of rocks in the fault zone and change in the joints pattern (Fig.9).

– **Geotechnical evidence:** The results of geotechnical studies indicate that the depth of bedrock in the central and southwestern sectors of line 1 is more than 60 meters with respect to natural ground surface (Fig.10), while in the northeastern sector it is only about 6.5 to 12 meters (Fig.11).

Fig.7: Cataclastic Rock in Ahwaz Reverse Fault Zone
(Area of Steel Factory of Ahwaz)

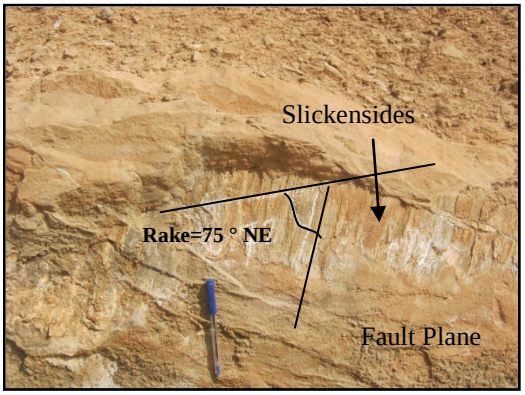

Fig.8: The plane of Ahwaz Reverse Fault
(Area of Steel Factory of Ahwaz)

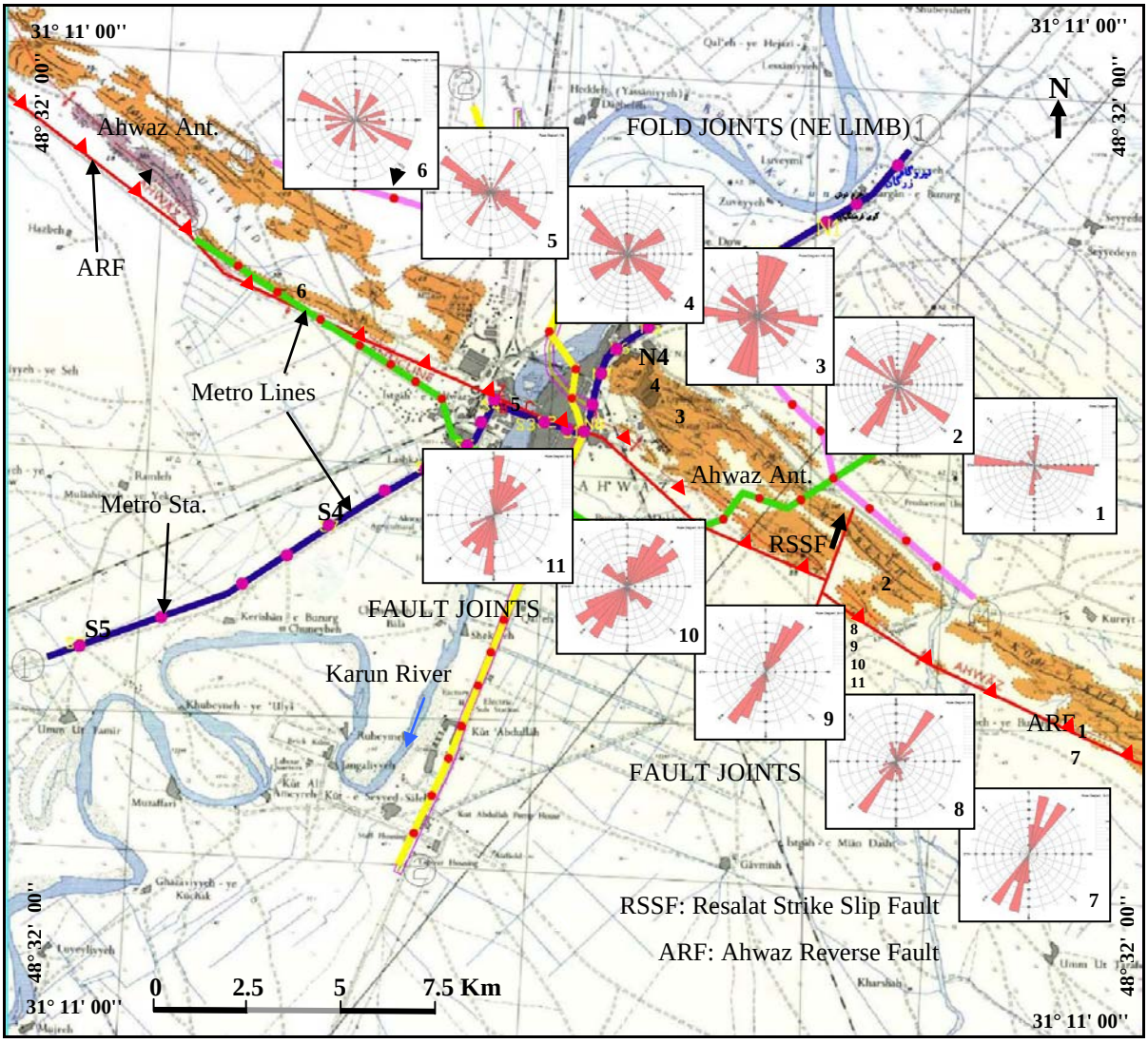

Fig.9: Joint systems in northeastern limb and fault zone of southwestern limb of Ahwaz anticline
(Adapted from Geological Map Sheet no. 20829E, scale 1: 100 000 IOOC)

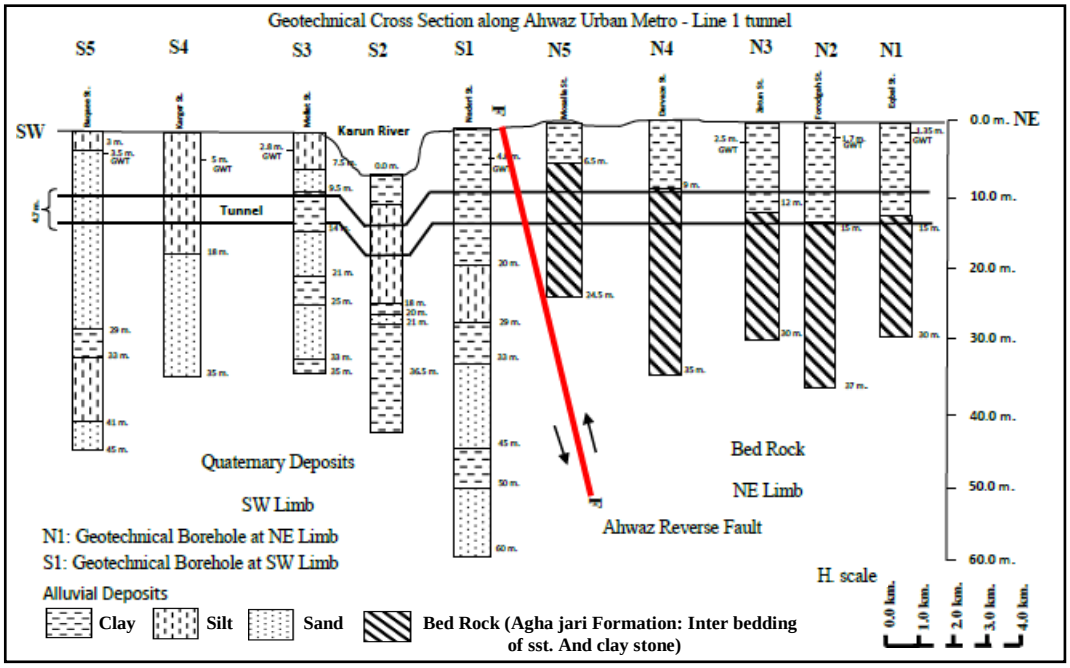

Fig.10: Intersection of Metro line 1 tunnel with Ahwaz reverse fault

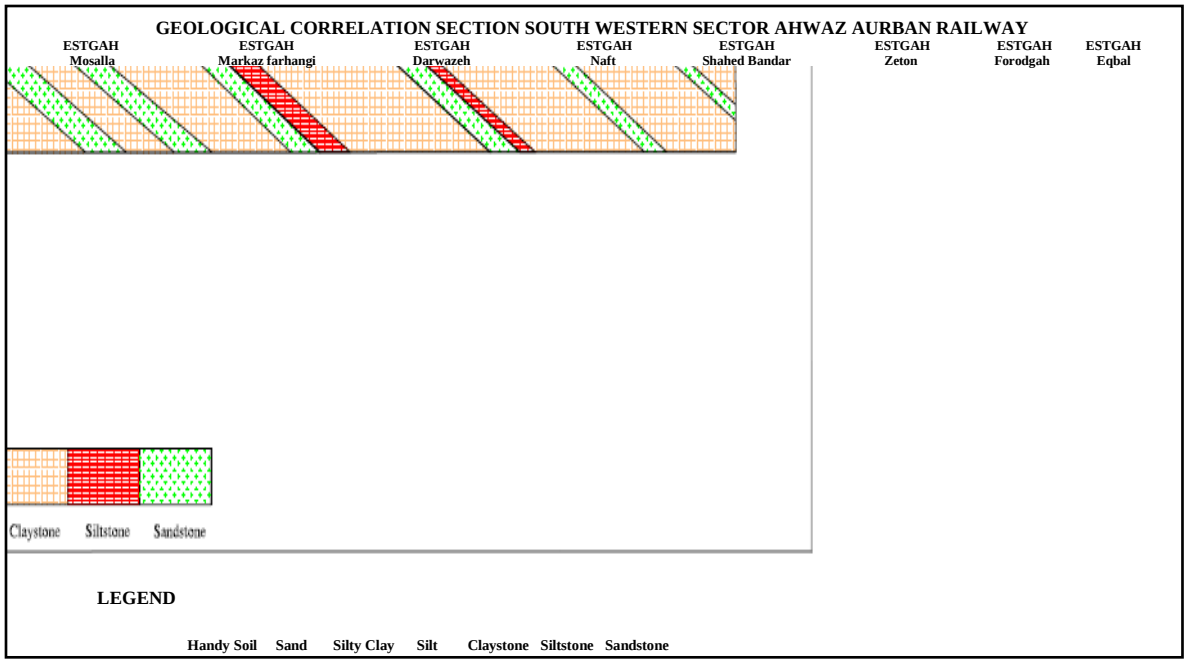

Fig.11: Northeastern sector of Metro Line 1 tunnel

The difference in the depth of the bedrock is due to the ancient tectonic activity of Ahwaz reverse fault which intersects line 1 tunnel at the end point of the northeastern sector. The southwestern sector will be constructed within the area of hanging wall of the fault which is covered by Quaternary deposits (Fig.12 and 13).

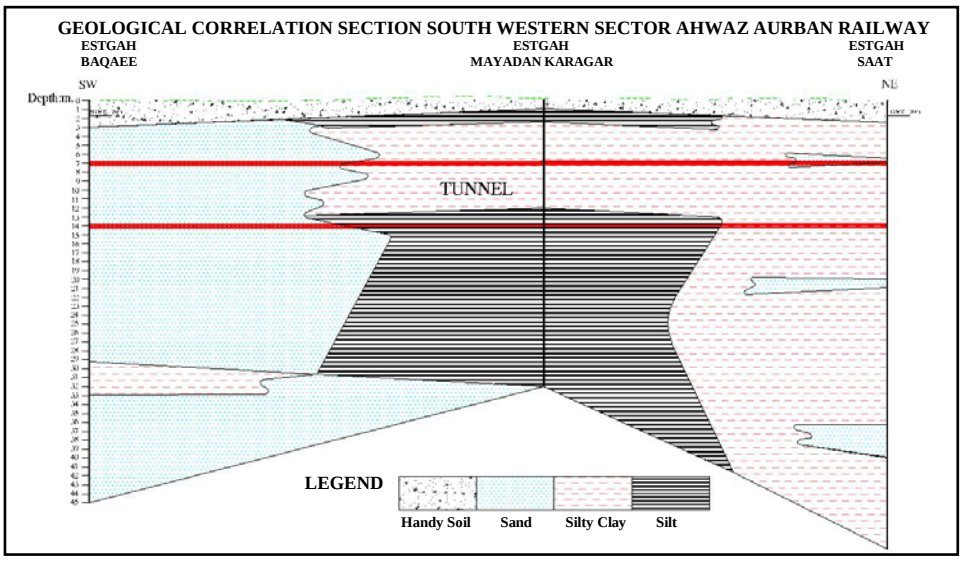

Fig.12: Southwestern sector of Metro Line 1 tunnel

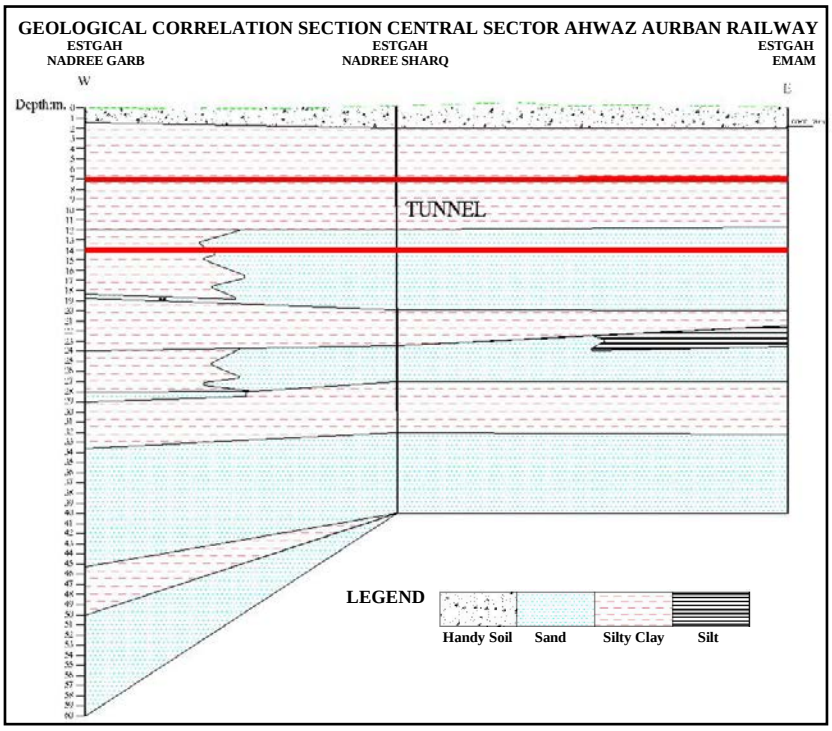

Fig.13: Central sector of Metro Line 1 tunnel

GEOLOGICAL HAZARDS

- **Crushed rock deformation in the zone of intersection of metro line 1 tunnel with Ahwaz reverse fault**

Field observations and geotechnical evidences indicate that the intersecting point of line 1 subway tunnel with Ahwaz fault zone is located along Serose Street, between Mosalla and Naderi stations (Figure 14). The maximum deformation in the crushed rocks surrounding line 1 tunnel will occur in the area that runs parallel to Ahwaz fault zone during earthquakes (Figure 15). An earthquake with magnitude 6/5 on the Richter scale has occurred in Ahwaz

city area (IISSE). A resistant and flexible lining for the tunnel at the intersection zone with the fault is required.

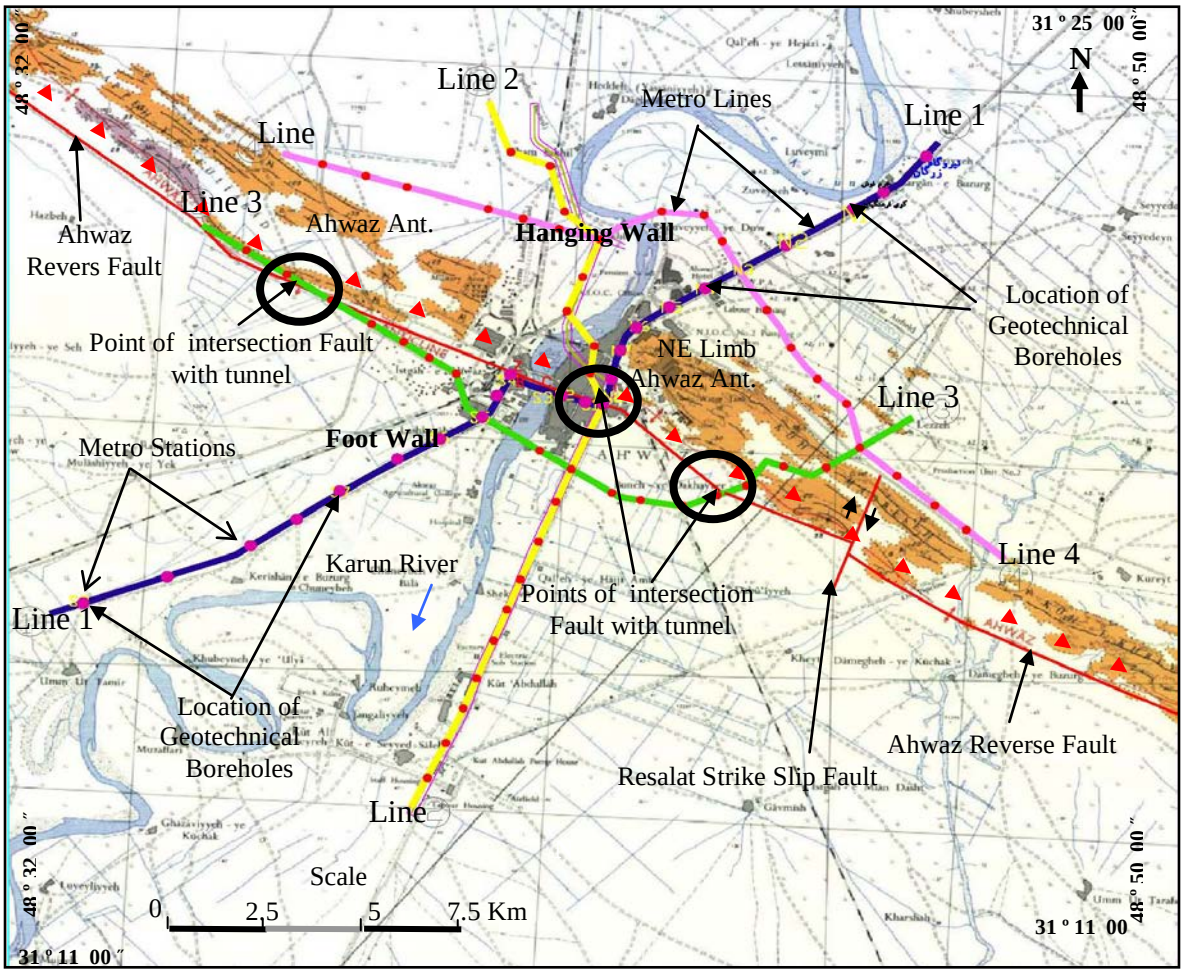

Fig.14: location of intersection points of Metro lines with Ahwaz reverse fault. Adapted from Geological Map, Sheet no. 20829E, Scale 1: 100 000 IOOC

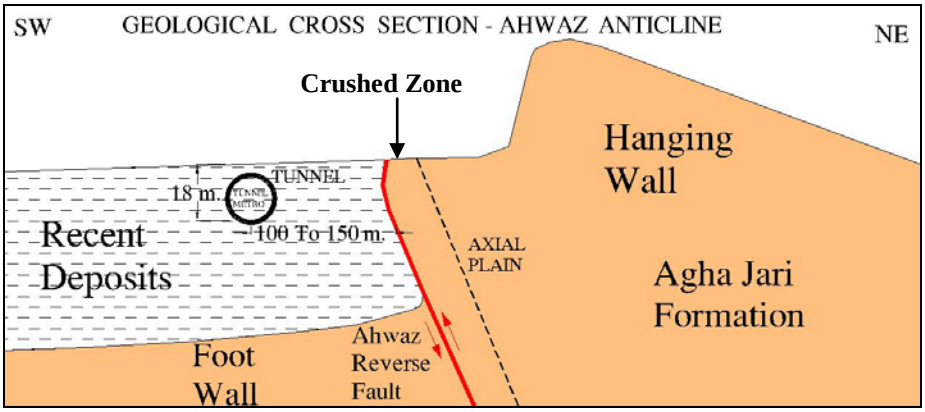

Fig.15: Schematic cross section showing the location of a crushed zone of the Ahwaz reverse fault relative to the central sector of Metro line 1 tunnel. The distance of the axis of the tunnel to the fault zone is 100 to 150 m and the depth of the base of the tunnel is about 18 m

- **Hazards of Adhesion and Clogging Risk**

Such risk will occur between the shell of the Tunnel Boring Machine (TBM) and the mudstone layers located in the northeastern part of line 1 subway tunnel. Most of the problems in this aspect belong to the clayey soils whose Plastic Limit lies between 20 to 60 percent and their consistency index between 1/75 to 1/30 (Thewes, 1999). Geotechnical studies which have been conducted along the line 1 subway tunnel indicate that such risks exist in some parts of the tunnel (Figure 16). Clay consistency index (Ic) is calculated by the following formula:

$$Ic = (LL - W\%)/ (LL - PI) \quad \text{.......} \quad (1)$$

LL = Liquid Limit, PI = Plasticity Index, W% = Water Content

The role of structural elements of the Ahwaz anticline in this case is the change of dip and strike values of claystone layers which have taken place between N82W, 20NE to N55W, 45NE.

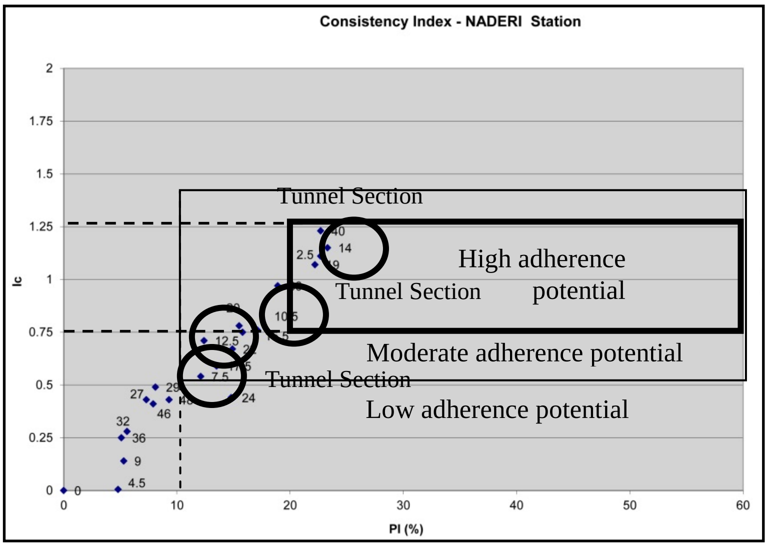

Fig.16: Nadri Station, Local section tunneling toward the limits of adhesion potential of clay. Places are in a high, moderate and low levels of clogging risk. The numbers beside the blue dots indicate the depth of the test sample relative to the surface normal

- **Creation heterogeneous job front at cutter head and reduce feed rate or performance of TBM**

The Unconfined Compression Strength (qu) of the rocks located in line 1 tunnel vary between 4/68 to 124/8, the adherence resistance ranges from 4/77 to 13/77 and the shear resistance from 0/01 to 0/95 kg/cm². Also, the angle of internal friction of these rocks ranges between 15 to 57 degrees. So the changes of the geometry of the structural elements of the Ahwaz anticline will play a decisive role in increasing or decreasing area of explosion of resistant (sandstone) and flexible (claystone) layers and cause variation in cutter, cup machine shell, cup of backup equipment, lack of convergence in point tunneling and destroy the tunnel system maintenance (Ramoni, 2010).

- **Planar and wedge failure risk at roof, walls and tunnel section of metro line 1**

In situations where the angle between bedding planes of rock layers and the section of tunnel is 20 degree or less, a planar failure may occur. The resonance of wedge failure, which is affected by geometry of joint sets, occurs in the crushed zone of the Ahwaz reverse fault (Fig.17). In addition, the risk of falling wedge or key blocks from the tunnel roof and walls is illustrated (Fig.18). The existence of risk in the unstable tunnel during earthquakes has also been investigated (Figs.19 and 20).

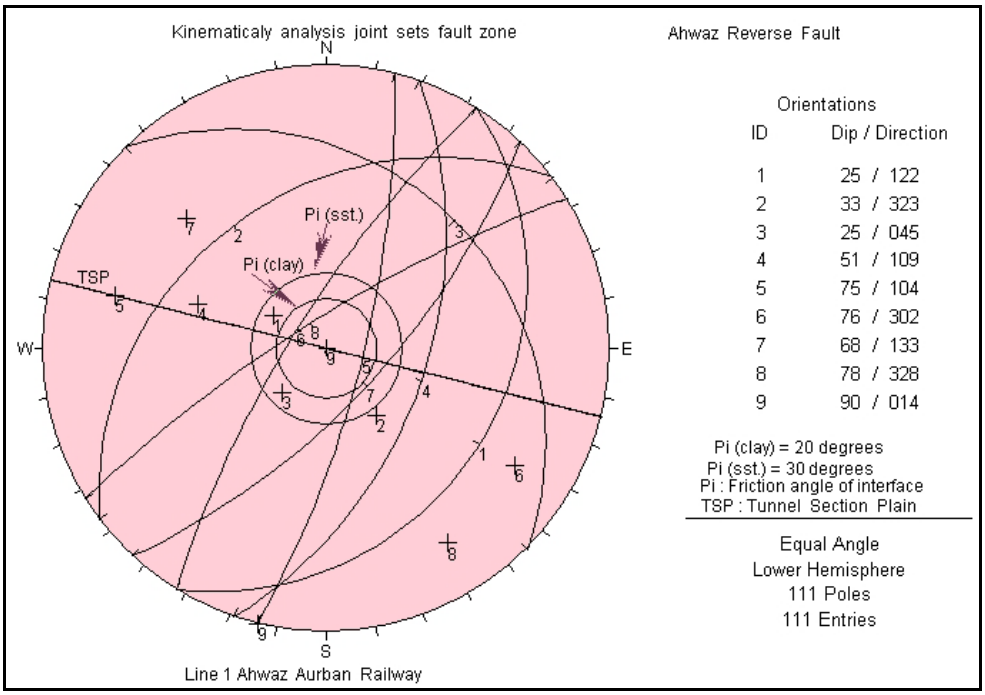

Fig.17: Kinematical analysis of wedge failure at Metro line 1 tunnel, sector intersection Metro line 1 tunnel with Ahwaz reverse fault zone

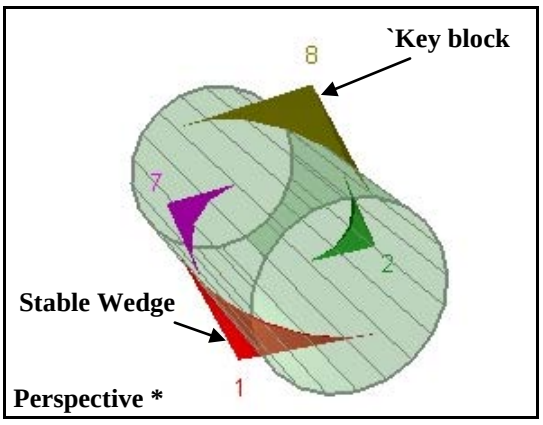

Fig.18: Three-dimensional view of the unstable and stable wedges in Metro line 1 tunnel (Naft Station)

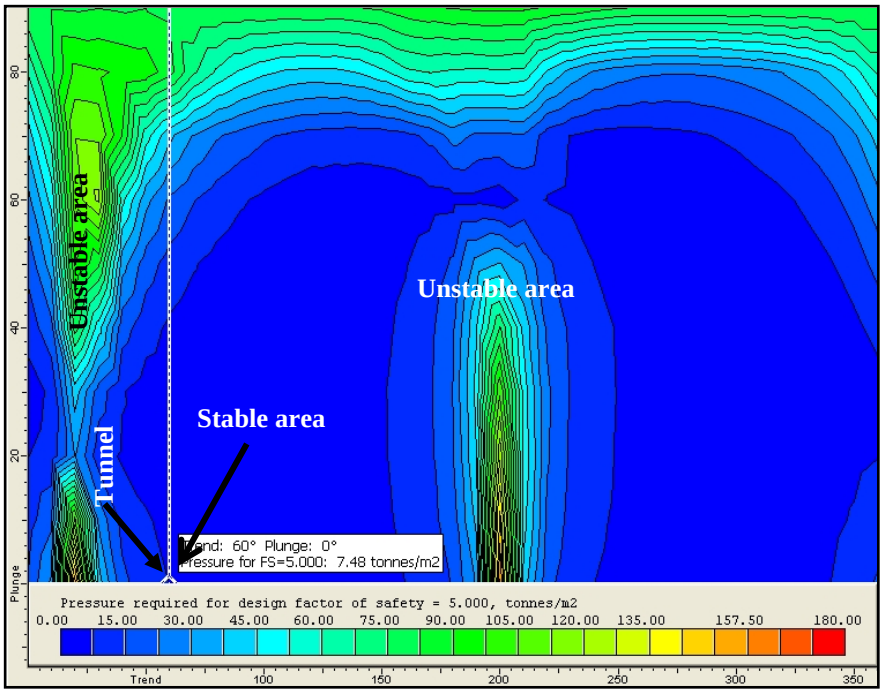

Fig.19: Placement of Metro line 1 tunnel at stable area in conditions of earthquake (Naft Station)

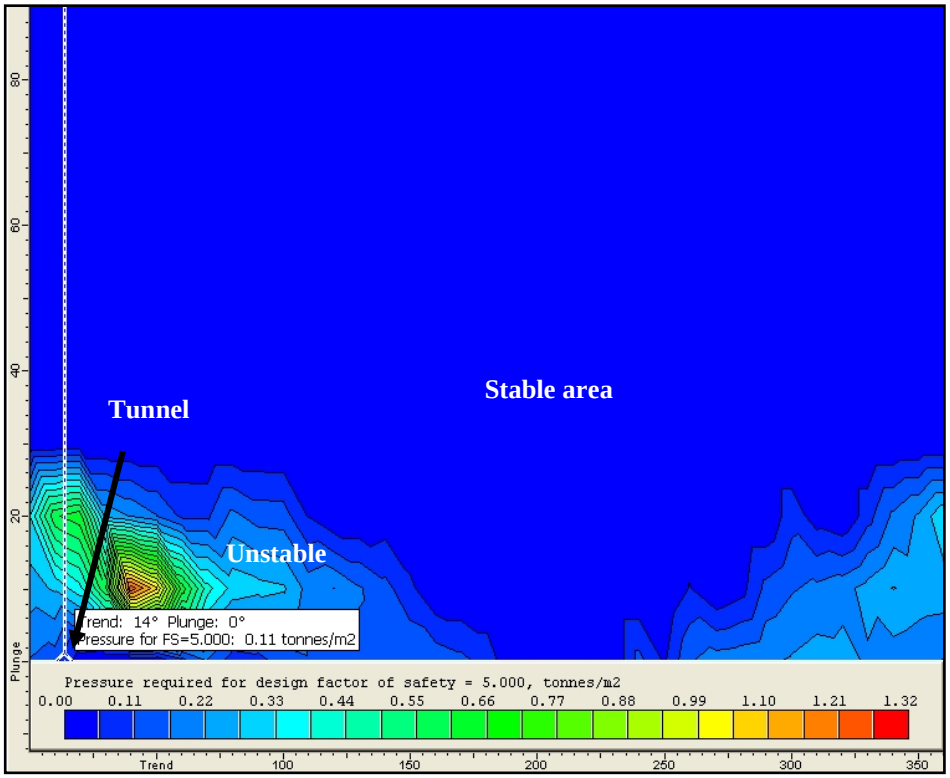

Fig.20: Placement of Metro line 1 tunnel within stable area at conditions of earthquake (Fault zone area)

CONCLUSIONS

Metro Line 1 tunnel in the area of crushed zone of the Ahwaz reverse fault is unstable during an earthquake. Also the position of this line within the zone of the adhesion between the shell of TBM and the mudstone layers will cause clogging risk. The outcrop of sandstone and claystone layers with different shear, uniaxial and adhesion resistances in the job front of the tunnel diverts the cutter head and hence the performance of TBM. Finally, the possibility of a wedge failure in the roof and walls of the tunnel reduces the safety factor to zero.

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Dr. Ebrahim A. Mohammad, graduated from University of Mosel in 1976, with B.Sc. degree in Geology. He got his M.Sc. degree from University of Sestan and Balujestan in 2012 in Tectonics. His experience extends for more than 35 years in geotechnical and business Geological Engineering in several Advisory studies.

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