New Occurrences of Ninivite, Genesis, Field relations and their Structural and Depositional Setting in Northern Iraq

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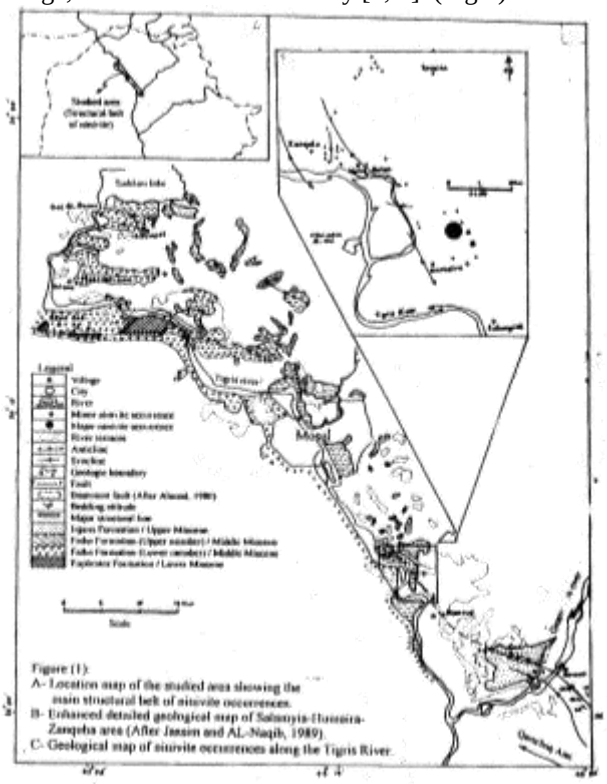
Abstract:

Ninivite is a new sedimentary rock type that forms a belt with a maximum width of six kilometers attached to the eastern bank of the river Tigris. Many other occurrences of this rock type are recorded in Guwair, Salymia, Humaira, Hawi Aslan and Zanquba villages, where it is normally found within Fatha and Injana Formations in different stratingraphic levels as well as the Tigris river terraces. The origin of this rock type is related primarily to paleo and recent hydrogeological regime of the Tigris River, although part of the studied localities are located on the Greater Zab. The new occurrences of Ninivite recorded in this work, along Guwair anticline adds a new evidence for the structural control on the formation and distribution of Ninivite. It is suggested here that the existence of ninivite in Guwair anticline is due to the probable deep seated faults controlled by block basement activation. This structural line extends from Guwair anticline to Zanquba village passing through Mosul and probably further northwest to Wana village. Other new occurrences were recorded in Mosul 'within the Tigris river channel', on Missrage anticline, in the western side of the Tigris river within the old qurray of Badosh cement factory and finally in the rock quarry near Babneat village.

Keywords :ninivite , alumite. Jarosite, Fatha, Humaira،

Introduction:

Ninivite is a new sedimentary rock type discovered and described for the first time by Al-Naqib in April, 1987 [1, 2]. The type area is located on a meander of the Tigris river water course 2km east-northeast of Humaira village, 25km south of Mosul city [3, 4] (Fig. l).



Minerallogically, ninivite is composed of amorphous silica (Opal-A, (disordered silica (Opal-CT) including; Alpha -cristobalite, Alpha- tridymite and Alpha-quartz [5]. Whereas the chemical analysis exhibits SiO_2 content that exceeds 95% (Table 1). It is clear that the analysis of [4] shows high SiO_2 content i.e. the samples are semi-pure rock in the type locality. Whereas, the analysis of (5) shows very low percentage of SiO_2 in sample (1) and this increases gradually towards sample (4). This is due to systematic sampling where sample (1) is from the outer zone (least altered calcareous marl) whereas sample (4) represent the almost pure ninivite that occurs in the inner parts of the alteration zone. However, contamination with gypsum as a by-product of ninivite formation is obvious from the analysis of [5]; analysis (1, 2 and 3) in Table (1).

Table (I): Chemical analysis of Ninivite.

Oxides	[٤]*	[٥]			
		١	٢	٣	٤
SiO_2	٩٤,٦	٢٥,٠٦	٥٠,١٤	٨٥,٨٦	٩٥,٧٠
Al_2O_3	٠,٧	٠,٢٨	٠,٣٨	٠,٣	٠,٢٢
Fe_2O_3	٠,٣	٠,١٨	٠,١٩	٠,١٢	٠,٠٨
CaO	٠,٦	٢٤,١	١٦,٩٦	٤,٢	٠,٩٨
MgO	٠,٠٧	-	-	-	٠,٠٢
Na_2O	٠,٠٢	-	-	-	-
K_2O	٠,٠٤	-	-	-	-
P_2O_5	٠,٠١	-	-	-	-
Cl	٠,٠٣				
SO_3	٠,٣	٣٣,٩٨	١٩,٠٠	٣,٤	٠,٠٧
L.O.I	٢,١	١٥,٩٣	١١,٨١	٤,٤٦	٢,٢
TiO_2	-	-	-	-	٠,٥٩

*Average o f 10 samples

The physical properties of ninivite and the coexisting rocks in the study area are shown in Tables (2 and 3). The surface area of ninivite has been measured by many workers; [6] calculated a surface area of 765.7m^2/gm, [7] showed that the surface area is 739 m^2/gm, whereas [8] stated that the surface area is 800m^2/gm.

Table (2): Physical properties of ninivite and the surrounding rocks.[٩]

Rock type	Porosity %	Density (g/cc)	Water absorption%	References
*Ninivite	-٦٢,١ ٧٦,٠٦	-٠,٦٧ ٠,٧٨	١٠٤,٧-٩٣,٤	Present study
Silty marl	-٢١,٤ ٣٢,٩	-١,٦٧ ٢,١	١٨,٦	[١٠]
Sandstone	-٢٣,٨ ٢٥,٥	-١,٨٧ ١,٩٤	٢,٤٣	=
Sandy marl	-٢١,٢ ٣٠,٥	-١,٦٧ ١,٩٨	١٧,٣٥-٩,٤٩	=
Clayey sandstone	-٢١,٤ ٢٩,٣	-١,٨٣ ١,٩١	١٠,٨٨	=
Limestone	٢٩,٩-٨,٤	-١,٧٩ ٢,٢٤	١٧,٩٧-١,٣	=
Gypsum	٤٨-١٨	-١,٩ ٢,٧١	١٩,٠-٠,٩	=
Marl	-٢٠,٠ ٣٧,٥	-١,٥٥ ٢,٠١	١٦,٠٢-٥,٣	=
Clayey gypsum	٢٥,٦-٦,١	-١,٨٧ ٢,٠٩	٢١,٩-٤,٥٧	=
Gypsiferous marl	-١٨,٥ ٣٣,٥	-١,٧١ ١,٨٤	٢١,٤-٢,٦	=

*Range of (10) samples including the samples of Guwair and Mosul

Table (3): Permeability of ninivite and other sedimentary rocks " for comparison"[9].

Rock Type	Permeability (cm/s(	References
@Ninivite	٥•١٠*٦,٠٧-^-١٠*٦,٩	Present study
Sandstone	٥"١٠*١,٢-٧•١٠*١,٦	[١١]
Breccia	٦-١٠ *٤,٦	=
Limestone	٧-١٠ *١,٢-١٠-١٠*٧,٠	=
Calcite	"-١٠ * ٩,٣-"١-١٠ *٧,٠	:=
Dolomite	٦-١٠*٢,٠-٩'١٠*٤,٦	=
Hard mud stone	٦-١٠ *٢,٠-٧-١٠*٦,٠	=

@Range of (10) samples including the samples from Guwair and Mosul

Very scarce structural information are available on the structural framework of north and northeastern Iraq [12] divided Iraq into the thrust, folded and unfolded zones. Buday and Jassim[13] reviewed some regional works and divided Iraq into structural zones and subzones (Fig.2). Numan [14] divided the northern part of Iraq into Mosul and Kirkuk blocks; where the area of the present study extends along the boundary between these two blocks (Fig.3). In a recent work, Numan [15] introduced a plate tectonic scenario for the phanerozoic succession in Iraq. Finally, Mutib [16] studied the deep seated structures of Mosul area using geoelectric investigations and came with new conclusions concerning the deep seated faults and their reflection on the surface geology of the area.

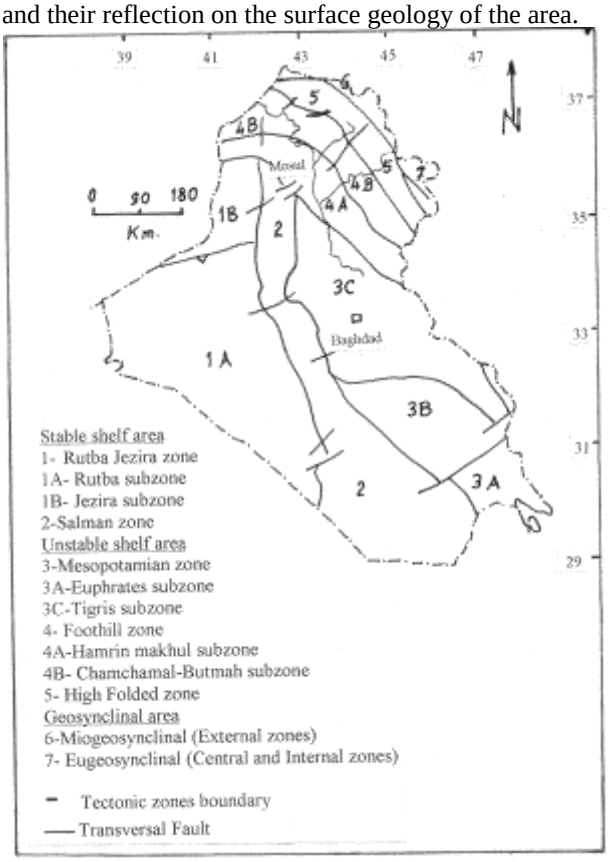


Fig. (2) Tectonic Map of Iraq (After Buday and Jassim, 1987).

Genesis:

Field relations show that ninivite is associated genetically with alunite $KAl_3(SO_4)_2(OH)_6$, jarosite $KFe_3(SO4)_2(OH)_6$ and gypsum $CaSO_4.2H_2O$. Aswad [5] discussed the genesis of this mineral association in detail. The general pattern of zoning due to alteration-precipitation embraces silica in the centre, followed outwards by alunite which in turn is surrounded by a relatively narrow zone of uneven distribution of jarosite and finally iron oxides occurring in the outer zone. Secondary gypsum may associate silica due to alteration which is inferred from the coexistence of clay minerals particularily illite with alunite-jarosite in the altered marl (Fig. 4).

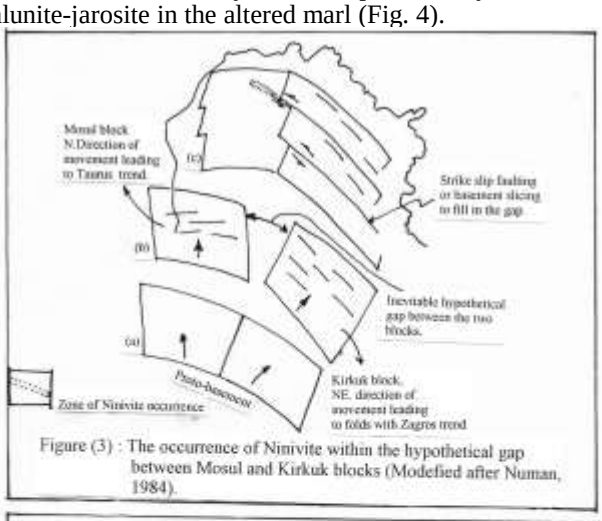


Figure (3) : The occurrence of Ninivite within the hypothetical gap between Mosul and Kirkuk blocks (Modefied after Numan, 1984).

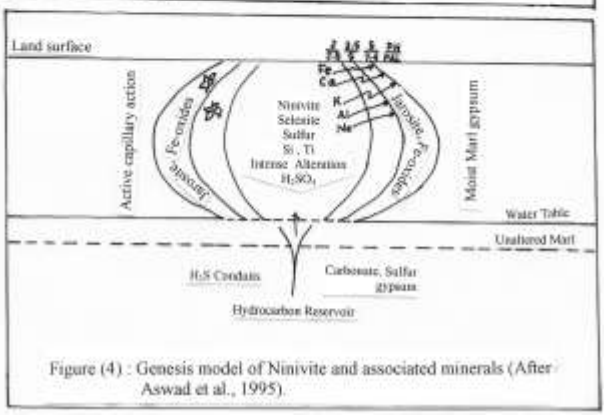


Figure (4) : Genesis model of Ninivite and associated minerals (After Aswad et al., 1995).

During sulfuric acid-marl interaction, dissimenated carbonates preferentially dissolve and migrate in solution and eventually precipitate gypsum as follows؛

$$CaCO_3+H_2SO_4+2H_2O \text{ —} CaSO_4.2H_2O+H_2CO_3 \text{... .(1)}$$

The reaction continues to buffer the system i.e. raising the pH above 4.5 until calcium is depleted and mobilized vertically and laterally as ionic species [17,18]. Concomittantly or soon afterwards, under the influence of slightly acid condition (pH=4.5), the reaction between degraded illite or kaolinite with sulfuric acid may produce alunite as follows:

$$KAl_3Si_3O_2(OH)_2+4H^{+1}+2SO_4^{-2} \text{ —— >} KAl_3(SO_4)_2(OH)_6 + 3SiO_2 \quad \text{. ..(2)}$$

and by continuous supply of illite from the unaltered illite -bearing parent rock, the following reaction took place؛

$$٣Al_2Si_2O_5(OH)_4+2K^{+1}+6H^{+1}+4SO_4^{-2} \text{ —>} 2KAl_3(SO_4)_2(OH)_6 + 6SiO_2 + 3H_2O \text{ .. (3)}$$

These reactions may cause partial alunitization. The coexistence of alunite illite and kaolinite in the transitional zone of the altered marl indicates equilibrium where both illite and kaolinite changed to alunite with increasing H^{1+} and $SO4^{2-}$ activities. Staibility fields indicate that this can be applied with jarosite where Fe^{+3} can replace Al^{+3} in the structure.

Stratigraphy:

The Fatha Formation (M.Miocene) is exposed in the core of anticlines that extend from Guwair to Mosul where ninivite occurs within the calcareous marl beds at different stratigraphic levels as well as within Injana Formation and Tigris river terraces.

The Fatha Formation was deposited in a cyclic fashion of marl, limestone and gypsum [19, 2]. Detrital sediments such as sandstones and siltstones persist within the upper member. In addition, thickly bedded alternation of noduler gypsum and marl are dominant as well as the frequent presence of red and reddish brown mudstones within the upper member. The clastic-nonclastic ratio increases radically within each individual cycle as the formation goes younger [20, 21].

The formation is overlain transitionally by Injana Formation (U. Miocene) that consists of sandstone, siltstone and mudstone which were deposited in fining upward cycles reaching a thickness of about 120m. However ninivite is found within the calcareous -rich mudstone beds.

Injana Formation is transitionally overlain by Mukdadyia Formation (Pliocene) indicated by the first appearance of a pebbly quartzitic sandstone bed [19]. The Mukdadyia Formation is composed of alternations of pebbly sandstones, sandstones, siltstones and mudsones. The formation ranges in thickness from 65m in Guwair area to 680m in the high folded zone further to the northeast of Guwair area. This thickness fluctuation is mostly related to its fluvial nature of deposition.

River terraces of both the Tigris and Greater Zab rivers overly unconformably these formations. Five stages of Tigris river terraces were mapped by [22] for the area extending from Salymia in the southeast to Dao -AL-Qamar village in the northwest where a strong field relationship between the Tigris river terraces and ninivite formation is found. During his carrier in the detailed geological mapping of Guwair area for the proposed Guwair dam, the author mapped three stages of the Greater Zab terraces [23] and found that there is no relationship between ninivite occurrences and the Greater Zab river terraces, where the highest level of the older terrace stage of the Greater Zab river is lower than the ninivite occurrences by more than 20m. This may indicate the occurrence of ninivite in Guwair anticline was related to the Tigris rather than greater Zab.

Results and Discussion:

In studying the area located between Hammam AL-Alil-Humaira, Hawi Asian and Zanquba on both sides of the Tigris river, [20] detected abrupt facies changes within the sediments of the Fatha Formation. This appears in the upper member where more clastic detritus were added to the lagoonal basin on the expance of the limestone and gypsum. In addition to the area of concern, east of the Tigris River (Humaira, Hawi Asian, and Zanquba), Shows extensive diagenesis reflected by high degree of crystallanity of the limestone marker beds No.2 ٤ ،٣ ،and 5 which were used as skelton marker beds for detailed mapping along with the smell of H_2S gas. These criteria combined with the longitudinal arrangement of acid seepages in the eastern side of Tigris River that are accompanied by occurrence of ninivite along the longitudinal NNW-SSE belt can be used to define the boundary between Mosul and Kirkuk blocks or places of minor block activation. (Fig. 3). This indicates that during Middle Miocene, particularity from the commencement of the deposition of the upper member of Fatha Formation; the basement blocks began to be activated thus affecting the depositional scheme of the upper member on the eastern side of the river and, hence, forming a syndepositional fault along the present trend of the Tigris river.

Structural and depositional setting

The present structural belt, enriched with ninivite rock, is bounded to the east by the boundary separating Chemchemal-Butmah subzone (4B) from Hamrin-Makhul sub-zone (4A), and to the west by the Tigris River, whereas extending in the south from Guwair structure to Wana village in the north (Fig.2). Thus, coinciding with the block basement fault (BF1 and BF2) and continues by a strike slip fault (SF2) in Mosul area defined by [16] (Fig. 5). He regarded SF2 as an inherited fault of horizontal movement that affected the eastern block and directed it towards the northeast, whereas the western block was directed to the northwest. The displacement of the BF2 on the Euphrates Formation reaches about 100m, and decreases on Fatha Formation [16].

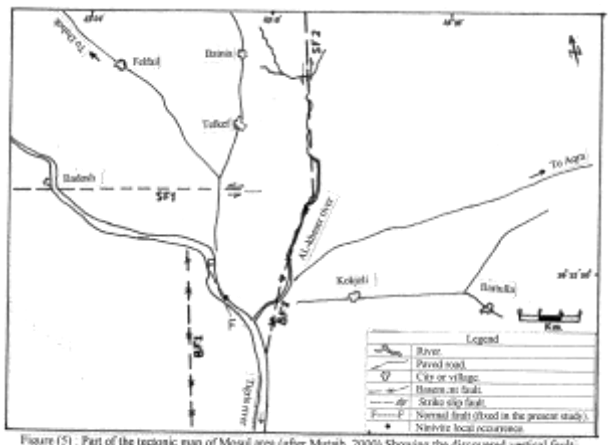


Figure (5) : Part of the tectonic map of Mosul area (after Mutaib, 2000) Showing the discovered vertical fault along Tigris and ninivite occurrence

This indicates that at early Middle Miocene, quiet lagoonal environment prevailed that led to the deposition of the lower member of Fatha Formation.

During Middle to late Miocene the reactivation of the basement blocks took place; marked by the deposition of the clastic detritus (red sandstones and mudstones) in the upper member of Fatha Formation. This interpretation is concordant with the clastic detritus appearance in the beginning of the deposition of the upper member of the Fatha Formation. Thus the clastic detritus increase in thickness vertically forming bird-foot deltas [20] where the Fatha lagoon is enriched with elastics and passes to Injana, Mukdadyia and Bi Hassan Formations. This faulted zone is assumed to be the continuation of the fault along the Tigris river detected by [24.[

Numan [14] stated that minor basement blocks play an important role in the location and configuration of small basins that received thicker sedimentation and later on were the sites of anticlinal structures . This fact is proved by the initiation of Guwair, Humaira, Hawi Asian,

Zanquba, and Mosul anticlines extending to the NNW towards Wana village passing through Missrage village, where Missrage anticline runs in E-W direction following the Tigris river orientation to Bab Neat village, Fig.(l). These anticlines are characterized by relatively steeper southeastern limbs and gentler northwestern limbs. Consequently this suggests that the geometry of these structures reflects basement activation along longitudinal lineaments parallel to the anticlinal structures [14.[

During Pliocene extensive folding, basement faults rejuvenations and isostatic bouyancy developed took place, where the main tanjential force was directed towards N-NE accompanied with the longitudinal basement faults, parallel to the fold axes [15] which are responsible for the evolution of H_2S gas. H_2S gas seepage is probably derived from deep seated oil fields and/ or as a by-product of sulphure formation; where the sulpher was oxidized by Thiobacillus thiooxidans bacteria [27] in the presence of water. The evolved gas moved upwards through the extension of the longitudinal basement faults and the associating fractures to produce acid solution that led to the dissolution of calcium carbonate in the calcareous marl leaving silica rich rock (Ninivite) and hence leaching ofAl^{+3} and Fe^{+3} to produce both alunite and jarosite respectively.

The swing of axis of Guwair, anticline clearly marked by the position of the Greater Zab river and the unclear en-echelon pattern of Humaira,, Hawi Asian, and Zanquba anticlines can also be considered as a reflection of the transversal basement lineaments that were extensively activated during or soon after the development of the anticlines.

Numan and Al-Azzawi [25] concluded that any of the folded structures embracing major longitudinal high angle normal faults can be considered as a reflection of basement faults, depending on the theory of tectonic basement blocks and strike slip faults tectonism. This fact matched the quastioned case of faults fixed in the channel of the Tigris river in Mosul city and their extensions towards the northern and northeastern parts.

A gravimetric survey made by [26] assured the presence of a deep seated basement fault along the axis of the swing portion of the Guwair anticline (Fig. 1).

Field relations

The author discovered number of occurrences of these rocks according to their relative position to the paleo-groundwater table levels related to Tigris river. On the other hand there has been any recorded existence of these rocks below the present water table level of the Tigris river (the 5th stage) where boreholes have been drilled by Geosurv and assured this fact. This shows the strong field relation between the early stages of Tigris river terraces and the existence of calcareous marls (the protolith of ninivite) within the stratigraphic column in the area.

The association of ninivite rocks with the Tigris river terraces, paleo and recent, suggest a genetic relation between the formation and devlopment of ninivite and the level of the ground water table, where the paleo ground water levels are detected by the presence of the old river terraces. Five stages of river terraces have been recorded by [22] for the Tigris river including the present one in the study area extending from AL-Salymia to Mosul Dam near the village Dao AL-Qamar.

The present development stage of ninivite

The ninivite bearing rocks (within the 5th stage of Tigris river terraces) are situated at a level few metres higher than the present water table level of the Tigris river (i.e. within the areation zone of the underground watertable). Sulphur springs appear along a cliff of the eastern bank of the river in the area between Zanquba and Hawi Aslan Fig.(l) accompanied with occurrences of primary alterations and recent ninivite rocks. The associations of sulphur springs and ninivite rocks structurally coincide with the trend ofBF2 and SF2 of [16], Fig. (5). The same applies in Mosul area beneath the AL-Qadissyia bridge in the middle of the river channel. However, in the villages occurring by the river along a E-W line up to Wana, ninivite is recorded within the 3rd and 4th stages of the river terraces.

A detailed geological survey was conducted in the Guwair anticline [23 [where three terraces stages of the Greater Zab river were recorded. The occurrences of ninivite that appears in the core of Guwair anticline is related to the hydrogeological system of the Tigris river terraces and has no relation to the terraces of the Greater Zab . This is because the level at which ninivite is recorded in Fatha Formation is located above the highest Zab terraces ever found in the area. This may lead to that the age of Tigris river is older than that of the Geater Zab river.

Al-Dabbagh and Al-Naqib [22] and Al-Jubouri et al. [28], determined the relative age of the river terraces of the Tigris river as of Pliestocene- Recent. It is thus suggested here that the paleo and recent genesis of ninivite is controlled by the paleo and recent hydrogeological system of the Tigris River prevailing latter at the time of ninivite formation and, hence, the formation of ninivite in the core of Guwair anticline took place, within the late stage of Pliestocene and the beginning of the Holocene.

Conclusions:

It is apparent from the above that the formation and occurrences of ninivite is related to the following:

1. Calcerous marls.
2. The paleo and recent hydrogeological system of the Tigris river.
3. The formation and development of ninivite rocks is structurally controlled by the longitudinal basement faults, along which enough H_2S gas may have seeped to produce H_2SO_4. These basement faults extends from Guwair anticline to Salymia, Humaira -Hawi Aslan-Zanquba- Mosul towards the village of Wana, through a narrow structural belt bounded to the west by the Tigris river with a width of 2-6 kilometers.
4. The association of ninivite rocks with the Tigris river terraces rather than the Greater Zab terraces in the Guwair anticline indicates that the age of the Greater Zab terraces is younger than that of the Tigris river.

Further works

The author suggest extensive detailed geological surveys for this structural belt south of Guwair anticline and north of Wana village to know the probability of discovering new occurrences of ninivite rocks.

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تواجدات جديدة لصخور النينفايت، نشوءها وعلاقاتها الحقلية ووضعها التركيبي والرسوبي في شمال العراق

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الملخص:

النينفايت صخرة رسوبية جديدة تشكل حزام عرضه حوالي ستة كيلومترات ويقع على الضفة الشرقية لنهر دجلة . وقد تم تسجيل مواقع أخرى لهذه الصخرة في منطقة الكوير والسلامية والحميرة وحاوي أصلان والزنكوبة والذي يوجد عادة في تكويني الفتحة وانجانه وفي مستويات طباقية مختلفة اضافة إلى ترسبات مصاطب نهر دجلة . إن أصل هذه الصخرة يتعلق بصورة ابتدائية بالنظامين القديم والحديث لنهر دجلة ولو أن جزء من المواقع المدروسة تقع على نهر الزاب الأعلى .

إن التواجدات الجديدة المسجلة في هذا البحث هي في تركيب الكوير وتضيف دليل جديد حول الأصل التركيبي المنظم لتواجدات وتوزيع هذه الصخرة وقد أقترح هنا بأن وجود النينفايت في تركيب الكوير المحدب هو ربما لاحتمالية وجود فوالق عميقة ناتجة عن حركات البلوكات القاعدية . إن هذا الخط التركيبي يمتد من تركيب الكوير المحدب إلى قرية زنكوبة ماراً بمدينة الموصل وربما يمتد إلى قرية وانه التي تقع في شمال غرب الموصل ، وقد تم في هذه الدراسة تسجيل تواجدات جديدة في الموصل ضمن قناة نهر دجلة وتركيب مسرج المحدب في الجانب الغربي من نهر دجلة وضمن المقلع القديم لمعمل سمنت بادوش وأخيراً سجل تواجد في مقلع الصخور في قرية بابنيت.