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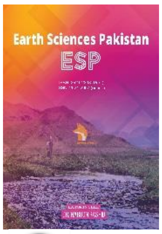

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RESEARCH ARTICLE

GEOLOGICAL EVALUATION OF LAKE VAN (TURKEY) FOR URANIUM-THORIUM DEPOSITION

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ABSTRACT

Purpose of this study is to prove most probable existence of economical U-Th mineralisations within Tatvan Basin which have been hidden among foreign international research project manuscripts of Lake Van and to inform the importance of national exploration studies. Lake Van is a pull-apart basin formed within Quaternary Muş-Zagros suture zone with right lateral movement. Calculations on heat transfer below the Tatvan Basin indicate that a constant heat flow is about fourty times the continental average which have been only reported from some oceanic ridges. Data indicate the heat source below Tatvan Basin bottom represents a steadily collapsing cauldron subsidence of Nemrut volcano's magma chamber. Lake Van surface water has mean 76ppb dissolved uranium content of hyrothermal and authigenic origin. It is calculated that there is at least 50.000 tons of dissolved uranium exists in the Lake Van waters**.** Ultimate deposition of U-Th mineralisation within euxinic Tatvan Basin have been expected to be a continuous process during geologic history of Lake Van as long as uranium resources remain and its $NaHCO_3$ water functions as dissolving agent Sodic Lake Van waters continuously dissolve uranium from 1) high 3He/4He and U-Th containing hydrothermal fluxes of mantle origin coming up through cauldron subsidence faults of Tatvan Basin, 2) per-alkaline rhyolitic volcanic ash rain of Nemrut volcanism, 3) Bitlis granitoid Massive basement, 4) repeated authigenic disentegrations of U to (Th and 4He) within the sedimentary deposites of Tatvan Basin through its 600.000 years history. Tatvan Basin is the deepest basin with 450m depth, 300km^2 flat area and constant unoxic basal water table undisturbed by currents and has the following verifications for Quaternary U-Th depositions in the unconsolidated porous sediments: 1) organic mass rich levels with reducing microbial activities, 2) evaporitic dolomites deposited during low stand lake levels with high U-Th concentrations, 3) varved, mixed-layered clays with high hectorite content, 4) sub-aqueous, basic-intermediate volcanic basement intrusions with reducing properties, 5) measured very low redox potentials in basal environment, 6) very high density of U-Th. Drilling core sequence and the gamma ray logs from Ahlat Ridge have been used in the foreign literature published since 1974 until now while the existence or non-existence of uranium has not been mentioned. Gamma ray logs of drilling cores and their pore water analyses from Tatvan Basin were carried out abroad but not published yet. Thus gamma ray logs belonging only to shallow Ahlat Ridge sequence where uranium mineral precipitation is not possible is misleading.

KEYWORDS

Tatvan Basin, Uranium, Cauldron subsidence, Peralkaline rhyolite, Sodic waters, Unoxic environment, Granitoid, Turkey.

1. INTRODUCTION

According to World Nuclear Association (2015)'s Nuclear Fuel Report; energy consumption growth rates of up to 10% annually over the past 50 years are much higher than we see for other commodities. Nuclear and solar are the only candidates for clean and cheep energy resources beside hydraulic, hydrothermal and wind energies. Uranium is more than 11,000 times more efficient in energy conversion than crude oil. The nuclear energy of uranium comes from some 440 nuclear reactors operating in 30 countries. The USA has over 100 reactors operating, supplying 20% of its electricity. France gets three quarters of its electricity from uranium. Uranium's finding costs make up only 2% while the oil finding costs are 12%. We also think that unfortunately some powerful countries try to intervene the energy resources of the world in various manners which are not justified.

In 1939, the first proven nuclear fission was performed by Otto Hahn in Germany. By this time the world was on the edge of war and military secrecy quickly surrounded the work of atomic scientists. A team led by Enrico Fermi built the first nuclear reactor in great secrecy at the University of Chicago. This pile achieved the first controlled nuclear reaction in 1942. Therefore, the importance of uranium neither on the field of energy nor for the military aspect were not known before 1939. Uranium had been used in glass industry for yellow colouring of the glass products before 1939.

Several comprehensive geological, geochemical, geophysical and core

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drilling studies within the basal varve deposites of Lake Van have been carried out by international research teams since 1974 through the following years of 1974-1978, 1989-1990, 1994, 1996, 2001-2004, 2006-2008, 2009-2012. The number of geological manuscripts of foreigners related to Lake Van are much more and beyond comparison than the number of other geological publications of foreigners related with other parts of Turkey.

Total many hundred meters long core drilling and their several kind electrical logs from the sedimentary deposits of the Lake Van basement have been obtained and their varve cores have mostly been examined in the German and Europian scientific laboratories, total many hundred kilometres long seismic profiles by ships and air magnetic survey anomalies were measured and all the necessary scientific studies have been carried out without limit on the Lake Van. The financement of these international geological projects on Lake Van have been supplied by foreign institutions, while Turkish Tübitak has shared a part of the financial and academician support for 2009-2012 Paleo-Van Project and MTA General Directorate supplied logistic and technical personel support in German Hamburg University's Project during 1974-1978.

It is interesting to see that such studies as the paleo-environment, paleo-climate, paleo-geochemistry, paleo-hydrogeology, paleo-biology, paleo-geography, paleo-tectonism for the waters and bottom sediments of Lake Van can turn out to be useful and employable scientific instruments and measurements for the exploration of the actual uranium thorium mineralisation. For example; sedimentary uranium mineralisation takes place within the intergranular cement or pore spaces. The pore space solution analyses of the drilling cores can also be utilised for the evaluation of uranium or radiogenic materials and their historical vertical migrations or enrichments. These pore water and core analyses have been carried out outside Turkey in foreign laboratories.

However, there has been no mention about the existence or non-existence of uranium - thorium mineralisation in the Tatvan Basin within contents of these international team studies. Unfortunately in the published manuscripts, Ahlat Ridge and Northern Basin drilling core logs are examined, but there is no knowledge about the 10 drilling core logs and their gamma ray logs of Tatvan Basin. Ahlat Ridge, as can be seen from the seismic sections, takes place between Tatvan and Northern Basins and at least 85m above the Tatvan basin floor while Northern Basin is 205m above (Figure 1). But possible actual sedimentary uranium mineralisation, can occur within unoxic environment of deep, subsiding Tatvan Basin. Some researchers, also support our claim by stating that "concentration gradients of main ions are different between the cores and obviously depend on the water depth of core recovery in Lake Van" (Reimer et al., 2009).

Sciences and technologies should be benefitable for all human kind with respect to their rights since knowledges and sciences have been common products of man kind. Lake Van is within Turkish borders for the last thousand years and Turkey needs uranium for its future nuclear electricity centrals. Lake Van as a whole contains several sub-basins like Deveboynu, Adilcevaz, Ahlat, Gevaş, Akdamar, Erikbağı and Northern all of which are shallower and smaller than Tatvan Basin. Their uranium deposition possibilities are much weaker comparing with that of Tatvan Basin. Actual thickest and richest sedimentary uranium-thorium mineralisations most likely occur beneath the Tatvan Basin, since dissolved uranium can inevitably deposit within the unoxic environment. As can also be seen in the seismic section (Figure 1), total thickness of Tatvan sedimentary deposites is twice thicker than that of Ahlat ridge.

Fırat University of Turkey, collected total 30 surface water samples from Lake Van and other samples from the neighbouring lakes and rivers in Eastern Anatolia in order to determine their environmental pollutions (Yaman et al., 2011). They have found that the Lake Van surface waters have dissolved mean 76ppb uranium concentration which is 55 times greater than mean sea water concentration. They calculated the existence of 50.000 tons dissolved uranium in NaHCO3 bearing Lake Van waters and shared this knowledge in a publication. If we imagine the whole water of Lake Van is evaporated, 50.000 tons of uranium will be deposited within the deepest part that is in Tatvan Basin. In addition Tatvan Basin has continuous unoxic reducing environmental conditions for uranium deposition. Yet the sources of dissolved uranium income within NaHCO3 bearing Lake Van waters have not been changed through 600.000 years of its history. The present total dissolved U quantity within soda bearing Lake Van's aquatic environment has continuous chance of dissolving and depositing since it sits over the rich uranium resources and deposits within deep unoxic reducing Tatvan Basin.

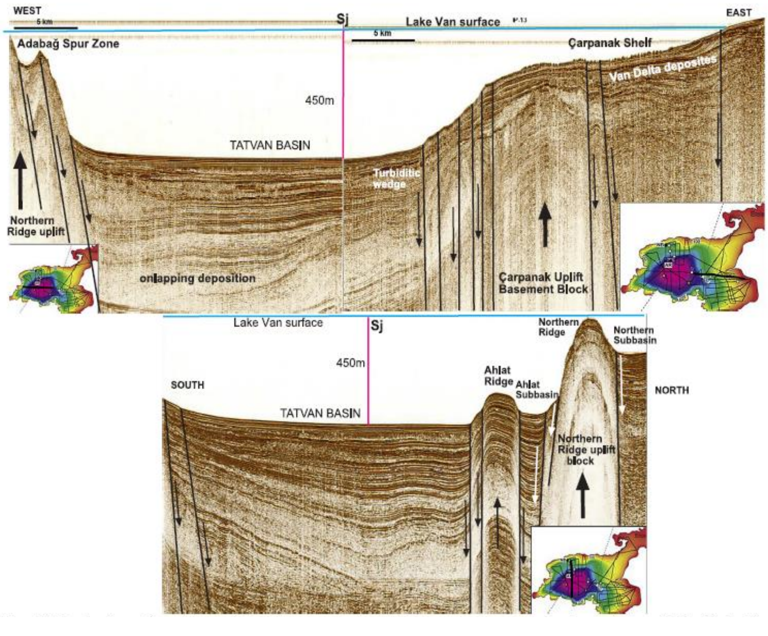

Figure 1: E-W and N-S seismic sections of Lake Van (Toker et al., 2017)

According to a study, Tatvan Basin has circular border in the middle of Lake Van having 450m depth and flat basement (Degens et al., 1978). It is situated on slowly emptying and sinking magma chamber of Nemrut volcanism. İn seismic sections we see graben structure of the subsiding Tatvan Basin representing ring fructures (Figure 1). Researchers calculated that there is an excess heat source undermeath the Tatvan Basin 40 times the continental average and basal volcanic intrusions through the ring shaped faults (Degens et al., 1978) which all indicate it is a caudron subsidence. A researcher states that as a result of crystal fractionation U is continuosly transferred from the mantle to the earth crust by hydrothermal emanations together with Th, K and 3H, 3He gases which issue from cauldron subsidence faults into deep euxinic environment (Figure 4) (Cuney, 2014). The precipitated uranium mineral concentration has always much greater concentration with respect to its dissolved equivalent in lake water as seen in Figure 9.

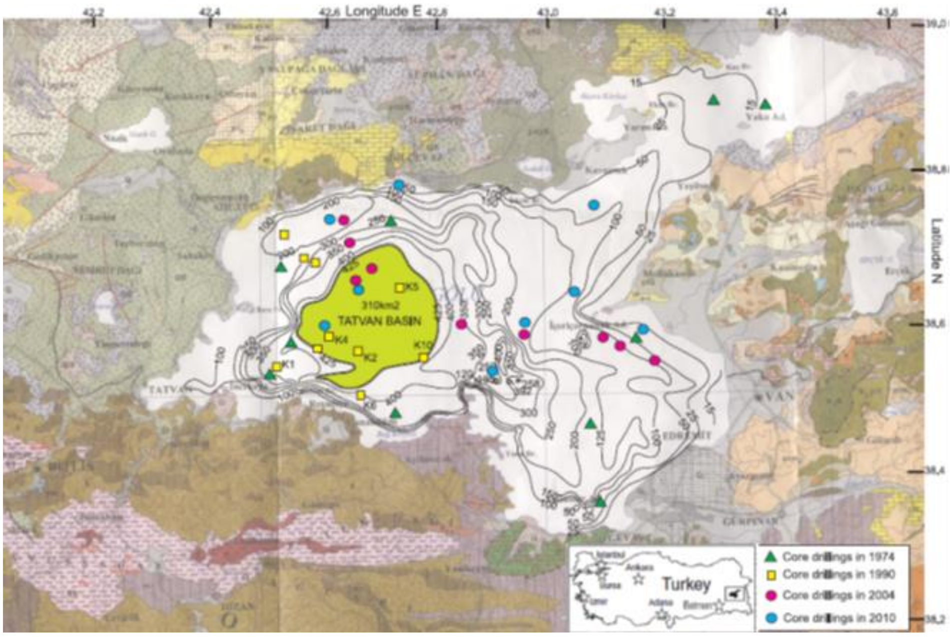

Figure 2: Geologic, Bathymetric maps and location area of unoxic Tatvan Basin, core drilling locations of Lake Van area. Nemrut and Suphan volcanoes outcrop at western and northern parts respectively and basal Bitlis ganitoid masive outcrops at southern part of the Lake (From 1/500,000 scaled MTA Geological map and from (Degens et al., 1978; Reimer et al., 2009).

We expect that an efficient and actual natural uranium depositional mechanism exists within Lake Van. Continuous Quaternary radiogenic uranium transfer from Nemrut volcano's magma chamber cauldron subsidence of Tatvan Basin, is dissolving within $NaHCO_3$ bearing waters and precipitating within the same deep unoxic basin. There are world wide important examples of similar caldera-like uranium depositional paleoenvironments such as the Streltsovka caldera of Russia and the Olympic Dam caldera of Australia and of Mongolia, China, Uzbekistan, and Kazakhstan which are known to contain large resources of uranium (Cuney and Kyser, 2009; Nash, 2010).

Without doubt, to learn economical existence of uranium beds within the basal sediments of Tatvan Basin and their reserves, qualities will only be possible by future Turkish core drillings and gamma ray log spectrometry, chemical analyse measurements. The need of uranium raw materials for the planned three future nuclear energy electricity centrals of Turkey which are going to be established will encourage such kinds of important explorations.

2. Geology

Lake Van is bordered by the Nemrut Volcano to the west, Süphan Volcano to the north, Bitlis gneissic granitoid massif to the south, and Eastern Anatolian Accretionary Ophiolitic Complex to the east. There are also a number of collapsed parasitic cones and domes in the south-southwest part of the lake (Figure 2). We need detailed geology of Tatvan Basin since it comprises probable uranium mineralisation so that the detailed regional geology is ignored. Bathymetry of Lake Van has importance for bordering the deep unoxic cauldron subsidence of Nemrut volcanic magma chamber which also forms the real and final euxinic depositional and evaporation site for the probable uranium precipitations through its history.

2.1 Bathymetry

The work described the division of the lake into three distinct physiographic provinces consisting of: a) a lacustrine shelf (27% of the lake area), extending from the lake shore to a sharp break in the bottom slope; b) a steeper lacustrine slope (sub-lacustrine slope, 63% of the lake area) c) a deep, relatively flat-plain basin province (10% of the lake area) in the center of the lake (Tatvan Basin) (Kempe and Degens, 1978). The deepest part of the lake, the Tatvan Basin, is completely controlled by surrounding gravity faults (Figures.1,2).

According to a study, during periods of high river water inflow and high water levels, renewal of the deep waters in the lake is prevented by the bathymetric topography and water stratification, causing anoxic conditions below depths of -300 m are developed (Table 1) (Kipfer et al., 1994). While during low water level incedences, surface area of Lake Van decreases quickly until deep Tatvan Basin borders are reached and Tatvan Basin forms the last remain of Lake Van to be evaporated (Table 1, Figure 2). Present lake surface is 1648m above sea level. Saline, 450m-deep Lake Van, with 607 km^3 volume and 3,570 km^2 area is the largest soda lake and the third largest closed lake on Earth. It has 12.470 km^2 drainage area fed by mostly Bendimahi and Zilan streams. Total annual water loss of Lake Van by evaporation is 4.2 km3 /yr and total water inflow by rain and snow precipitation is 2.5 km3/yr and by streams' income 1.7 km3/yr.

Table 1: The bathymetric surface areas of Lake Van between 300-450m depth become narrower and at 450m depth has horizontal basement with 300km^2 area (Degens et al., 1978).

Lake Van Depths (m)	Environmental Properties	Lake Surface Area (km^2)
0	Oxic Conditions	3574
25		2618
50	Epilimnion	2427
100		2074
150		1699
200		1315
250		1024
300	----------------------------------	866
350	Hypolimnion	696
400		442
425		310
450	Anoxic environment	300

2.2 Stratigraphy

Many comprehensive core drilling studies of Lake Van basal varve deposites have been carried out by international research teams since 1974. The PALEOVAN drilling Project, completed downhole logging operations in 2012 and obtained continuous data sets of downhole data (spectral gamma ray, magnetic susceptibility, dipmeter, resistivity, and temperature as well as partly sonic data) (Litt et al., 2012). The cores were opened in spring 2011 at the ICDP core repository located at the MARUM, University of Bremen. Successful International Continental Scientific Drilling Program (ICDP) of total 800m yielded a rich, temporally long and mostly continuous Lake Van sedimentary succession. In addition, this Van record have a higher resolution and will be better dated than all of these previous records.

A group researchers indicate that the lithostratigraphy of the Lake Van records distinguishes three main sediment groups: i) lacustrine clayey silt, ii) volcaniclastics and iii) coarse grained fluvial deposits (Kempe et al., 2020; Stockhecke et al., 2012). The varve structures of the Lake Van sediments form as a result of seasonal sedimentation producing a three-laminae structure in a year. Sediment trap studies, together with detailed geochemical and scanning electron microscopy analysis of cores, showed that an annual varve consisted of: 1) a non-skeletal algal and detrital mineral-rich lamina deposited during spring, 2) a light carbonate-rich lamina formed during the summer by evaporation, and 3) siliceous frustules-rich laminae formed during autumn and winter. Other group researchers also indicate that, due to the high alkalinity, silica containing diatome organisms are not preserved long after the cell death except the ones underneath the event deposites (Degens et al., 1978; Litt et al., 2009).

According to a study, the 219 m long sedimentary sequence of the main drill site at Ahlat Ridge (AR) covers the last 600 kyr, while the Northern Basin (NB) with 140m thick drill site covers the last 90 kyr (Figure 1) (Stockhecke et al., 2014). The drilled sequence consists of ca 76% lacustrine carbonaceous clayey silt, ca 2% fluvial deposits, ca 17% volcaniclastic deposits and 5% gaps. Some researchers also recognized a total of 19 lake Van-level changes with alternating regressions and transgressions (Cukur et al., 2014).

Uraninite, can precipitate within magnesium rich evaporatic deposites of low lake levels because dissolved uranium ion concentrations have intensely been increased. Dolomite formation is initiated at low water stands i.e. at times when Mg/Ca ratio in the lake was particularly high (Degens et al., 1978). It is not clear yet whether the dolomite precipitated directly from the water column or formed during early diagenesis from a carbonate precursor. The abundance of dolomites in the lower sections of the deep-water cores can only mean that the ancient lake stood at a much lower level than today to yield a magnesium level concentration favourable for dolomite formation. At times of evaporation dolomite comes in at the expence of aragonite. All aragonite is authigenic, the precence of reworked ancient fossils indicate that part of the calcite was detrital.

A group researcher state that Ca, in the past has been lost also as protodolomite during desiccation events (Reimer et al., 2009). Mg-depletion is caused by the neoformation of clay minerals or Mg-silica-rich precursors in the sediments. Mg-fixation largely occurs in the top layer of sediment and appears to be controlled by delivery and dissolution rates of diatoms emphasizing that magnesium and silica cycles in Lake Van are closely related (Figure 3). İn a study states that in the salt layers, U and Al concentrations correlate closely, implying that both derived mainly from the detrital fraction in the salt layers (Yang, 2014). However, enrichments of U and Mg are systematically higher in salt minerals formed in more concentrated brine and lower in those formed in less concentrated brine. These results indicate that during the process of carbonate precipitation, carbonate might effectively remove U from lake water as uraninite mineral deposition. During the subsequent stage of salt minerals precipitation, U behavior is conservative, and U resides for a long period in dissolved forms within the saline water, giving rise to enhanced U enrichment in the more concentrated brines and the associated precipitated salt minerals. Therefore sedimentary levels with dolomites and magnesium rich clays (hectorite) or similar type saline deposites are also uranium traping depository levels (Figure 3). İn a study, stated that the dissolved concentrations of atmospheric noble gases in the pore waters of the ICDP PaleoVan cores were used to geochemically reconstruct salinity on the time scale of 0-55 ka BP (Tomonaga et al., 2014). Higher salinities in the pore water at a depth of about 20 m suggested a significantly lower lake level of Lake Van in the past.

Some researcher interpreted that about 8000 years ago the Lake Van level fluctuated down by as much as 400m and the salinity range increased by almost a factor of twenty (Degens et al., 1978). At its lowest stand, Lake Van could precipitate Na_2CO_3 but never was a saturation point for NaCl reached. The abundance of dolomites in the lower sections of deep water cores can only mean that the ancient lake level stood at a much lower level than today to yield a magnesium level concentration favorable for dolomite formation (Figure 3). The consequences for the local biota must have been considerable. They interpret the gradual rise in organic carbon from a low of 1 % around 8000 years before present to a value 4 % in the modern sediments as a sign of increase in plankton productivity due to an improvement in the living conditions in the local habitat. Prior to 8000 years before present, organic carbon values increase with depth, a further indication of the deterioration of the environment around that time. A "salinity crisis" within Lake Van at 8000 BP must have established.

In addition to dolomitic levels, unoxic levels of the Tatvan Basin are candidates for depositional uranium traps. Spatial uranium associations with areas of wet paleoclimate in Lake Van (phytoplankton species including flagellates, green algae and especially diatoms and cyanobacteria), evaporite deposites (saline water, giving rise to enhanced U enrichment) (Figure 3) and basic to intermedier basal volcanic intrusions with reducing properties are deemed positive for uranium precipitation. Organic carbon, biogenic mass and microbial mats play positive role for the development unoxic sedimentary environments in which uranium precipitation and mineralisation can occur. Therefore we can select unoxic sedimentary argillaceous levels as possible uranium mineralisation levels which may also occur within saline deposites.

According to many study, air gun profiles showed the presence of up to 600 ka aged unconsolidated sediments, composed of extensive, well-stratified layers alternating with chaotical sediments reflecting event layers (Landmann et al., 1996; Lemcke, 1996; Reimer et al., 2009). The stratified sections were deposited during periods of normal sedimentation, while the chaotic layers are thought to represent slumps deposited during rapid changes in lake level that caused sediment instability and, hence slumping. Up to 10m long sediment cores were recovered from the Tatvan Basin of the lake Van, covering a time period of about 15 ka while 15ka time equivalent thickness at Ahlat Ridge is only 5m which indicates total depositional thickness of Tatvan Basin is approximately twice thicker than that of Ahlat Ridge and its tectonic subsidence.

In line with work on the spatial distribution of the terrigenic He release into Lake Van, they identified a high He concentration gradient in the uppermost 10 m of the sediment column (Tomonaga et al., 2014). The He concentration gradient decreases below this depth down to approx. 160 m following in general the expectations of the modelling of radiogenic He production and transport in a sediment column with homogeneous fluid transport properties. The overall in-situ radiogenic He production due to the decay of U and Th in the mineral phases of the sediments accounts for about 80% of the He accumulation within pore spaces. The presence of three depth ranges being characterised by different 3He/4He ratios 0-50 m: $(2.7 \pm 0.1).10^{-6}$; 50-155 m: $(2.1 \pm 0.1).10^{-6}$; 155-220 m: $(3.7 \pm 0.2).10^{-6}$ to the specific transport properties of the sediment pore space and to the dynamics of the terrigenic fluid emission into Lake Van. Probable authigenic uranium-thorium depositional levels of Tatvan Basin can approximately be correlated with radiogenic He levels.

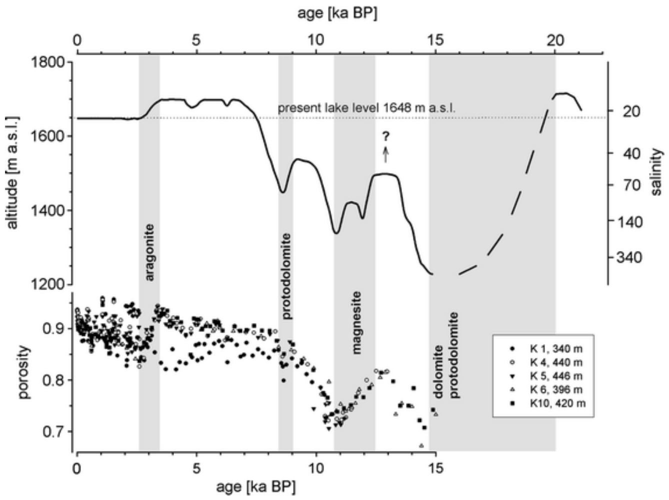

Figure 3: Lake level fluctuations of Lake Van in the past 20 ka and sediment porosity versus age. Shaded areas mark periods with negative water balance. Maximum depth of Lake Van today is 451 m, water depths of the cores are given in the legend and their locations are given in Figure 2. Note that the scale of the salinity axis is not linear (Reimer et al., 2009)

2.3 Magmatism

A group researchers indicate that Nemrut magmatism for ~570,000 years has been dominated by peralkaline trachytes and rhyolites (Macdonald et al., 2015). The phenocryst and glass matrix compositions of the tefra, confirming a complete spectrum from very rare mafic to dominantly silicic magmas. Its open-system nature is also indicated by the abundant evidence of mingling and lesser true mixing between mafic, intermediate and silicic magmas. In an extreme case, that plagioclase crystals with An >50 in peralkaline rhyolite were derived from a basaltic magma indicating magma mixing. Certain features of the Nemrut plumbing system of radioactive metal fractionation point to magma evolution in a stably stratified chamber which forms over thousands of years by crystal settling and upward migration of volatiles. Magma mixing has been common and along with the multi-lineage nature for the Nemrut volcanisim. An unusual Pb-rich phase, with up to 98.78 wt % PbO, is interpreted as having exsolved from the intermediate-rhyolitic magmas.

According to a study, volcanic tephra deposits of lake Van were supplied by four volcanic sources: 1) the Süphan volcano, located on the northern shore, 2) the Nemrut volcano, 15 km west of the western shore, 3) the Incekaya volcano, on the south-western shore and 4) intra lake eruptive centers (Baumgarten and Wonik, 2014). While in another study found that rhyolitic volcanic ash layers of Lake Van were peralkaline in nature (Degens et al., 1978; Macdonald et al., 2015). The heavy mineral composition shows an abundance in aegirine-augite. These chemical and mineralogical data lead them to conclude that the ash layers in the lake sediments are exclusively derived from Nemrut Volcano. The recovered drilling core tephra layers are dominated by Süphan tephras in the deeper sections and Nemrut tephras in the shallower sections. A group researcher indicate that Süphan rhyolitic and dacitic tephras carry plagioclase with low radiogenic yield, while Nemrut tephras are alkaline rhyolites and trachytes carrying anorthoclase as felsic phase with higher radiogenic yield (Litt et al., 2012).

Nash, 2010, states that magma mixtures are the sources of uranium. The existence of two phenocryst populations in some rocks is strong evidence that they are a result of magma mixing, which is already recognised within Nemrut volcanism (Cubukcu et al., 2012; Sumita and Schmincke, 2013a). According to a study, felsic peralkaline rhyolites, in which U is dominantly hosted in the glassy matrix, represent an excellent source for many depositional types of uranium (Cuney, 2014). In particular a wider use of the magmatic inclusions to determine the parent magma chemistry and its U content is of utmost interest to evaluate the U source potential of sedimentary basins that contain felsic volcanic acidic tuffs (Figure 4). A study reported uranium concentrations of 3 - 20ppm within Californian per alkaline rhyolitic tephras (Gray et al., 2010).

Calculations on heat transfer especially below the Tatvan Basin indicate that there is an excess in heat in the amount of 4.3×10^{13} kcal/yr which can only be linked to geothermal processes (Degens et al., 1978). Assuming a constant heat flow for the entire lake floor, they drive a value of 57.8 µcal $cm^{-2}sec^{-1}$ which is about fourty times the continental average of 1.49 µcal $cm^{-2}sec^{-1}$. Heat flow values of that magnitude have been reported from some oceanic rifts and deeper parts of some pull-apart lakes. The data suggest that a heat source must be located close to the lake bottom. The same heat source could be responsible for the Nemrut volcano, which has been active in historic times. According to a study, this type of heat excess beneath calderas is sourced by magma plumbing systems (Kennedy et al., 2018).

Tatvan Basin is situated over the Nemrut volcano's peralkaline rhyolitic magma chamber and formed a tectonic subsidence (Degens et al., 1978) (within basal Bitlis granitoid Massive) reaching the magma chamber. Magma plumbing systems beneath calderas develop incrementally as magma rises, intrudes and rejuvenates (just as Nemrut Mountain volcano (Photo1) (Kennedy et al., 2018). Eventually accumulation and eruption of a sufficient magma volume drives subsidence of the plumbing system roof to form a caldera. Some caldera subsidences, U and other radioactive enrichments and their continuous upward transfer from partial melting and fractional crystallisation of ultrabasic magma occur (Figure 4) (Cuney, 2014). Important example of uranium enrichment and reserve occurred at the base of Streltsovka caldera in Russia (Chabiron et al., 2003). Three sources may have contributed to the formation of the uranium deposits: (1) the peralkaline rhyolites filling the caldera, (2) the fluids expelled from the volcanic melts or from the underlying magma chamber, and (3) the subalkaline granitoid rocks of the basement.

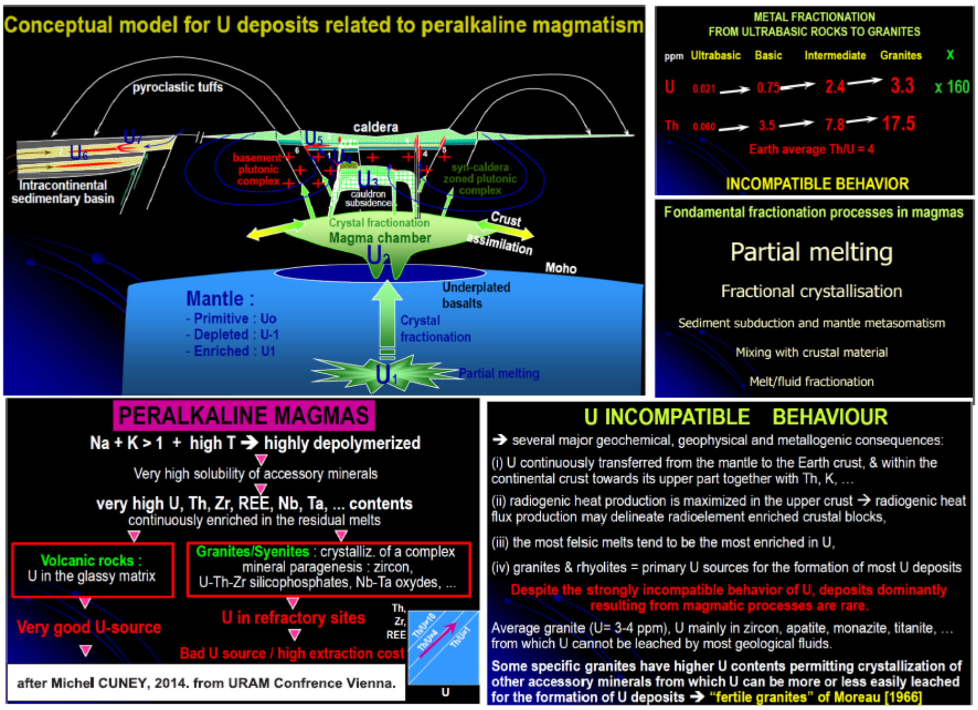

Figure 4: Geological model for the origin of probable uranium deposition within Tatvan Basin which can be formed by couldron subsidence of Nemrut volcanic magma chamber. The uranium concentration continued during its continuous transfer from the mantle to unoxic Tatvan basin in the granitoid Bitlis massive lithosphere.

We interpret that Jurassic Streltsovka caldera of Russia and Neogene phreatic Olympic Dam caldera of Australia have some similarities to Quaternary Tatvan Basin. Therefore enterence of radioactive emanations through the encircling faults into the unoxic waters of Tatvan Basin indicates the main historical source of dissolved U in Lake Van waters. While peralkaline rhyolitic ash of Nemrut Volcano and basal granitoitic Bitlis Massive may also be the other U sources at the base of the Tatvan Basin cauldron subsidence (Figure 4). Magmatic fissure intrusions or ring dykes occur around the margins of the central Tatvan Basin in the west, south and south-east parts (Figure 5) which are probably associated with the ring fractures.

The results of He isotopic studies revealed that the water of Lake Van contains excessive amount of radioactive He, indicating that tectono-magmatic activity is still in progress beneath Tatvan basin (Tomonaga et al., 2011). Radiogenic He emanations from Tatvan Basement can spatially be related to the basal cauldron subsidence faults reaching magma chamber. According to a study, the basement faults and fractures localize vertical He migration (Tomonaga et al., 2011 and Cuney et al., 2014). While according to a study, recrystallization/ dissolution will release essentially all of the generated helium at the time of magmatic recrystallization (Brown, 2010). Most of the helium is generated by radioactive decay of uranium and thorium and their daughter products. Helium generated in the deep crust cannot migrate to traps in overlying strata unless some fluid carries it out of the basement. Most He quickly partitions into the evolving hydrothermal gas or CO_2-rich hydrothermal fluids where heat flow is high.

According to a study, uranium with tritium and thorium can occur predominantly in mineral grains, not in pore water at sediment-water contacts (Brown, 2010). But authigenic radioactive decay of U and Th forms He which diffuses to pore water. He concentration in pore water increases with increasing U and Th concentration, increasing age, and decreasing porosity.

2.4 Tectonism

The geometry and kinematic indicators of southern lake Van suture zone faulting imply that its Quaternary movement is mainly dextral normal oblique (Toker et al., 2017). All the marginal fault systems appear to develop coevally and cut across each another (Figure 5 and Photo 1). The northern margin is subjected to transpression. This faulting episode strongly controlled the Northern Ridge. The folding of the sedimentary layers is completely confined within the deformation area in Northern Ridge of Lake Van and controlled by secondary faults. The faulting/ folding structures are related to the overall strike-slip displacements. The seismic sections show that the faulting in the south-margin of Lake Van has a structural complexity. This implies a complicated discontinuous faulting pattern of the southern margin. The southern margin is also highly characterized by the deformational activity of the rising intrusive bodies and collapsed dome-cone complexes (Figure 5, Photo1).

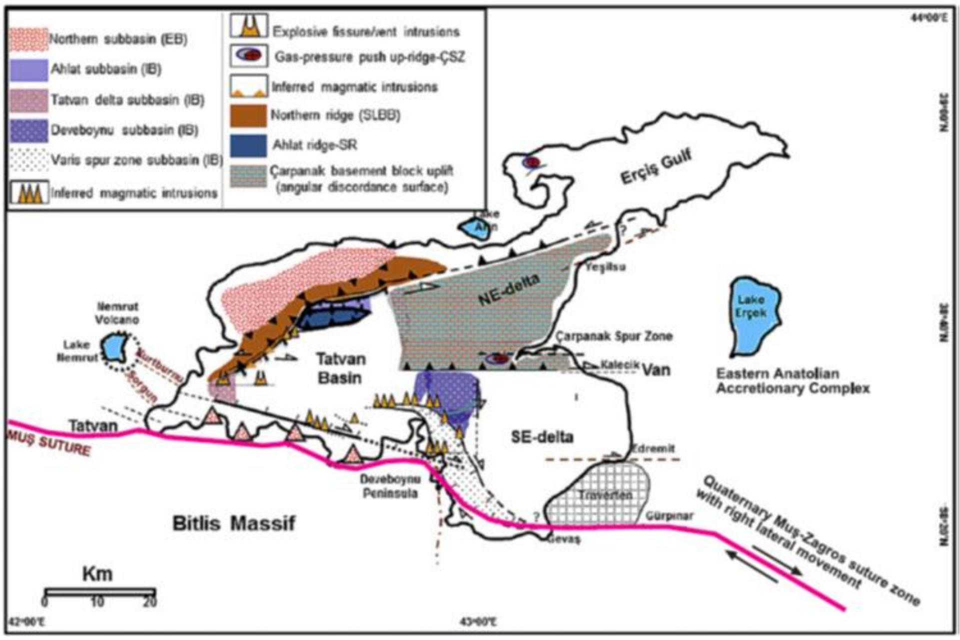

Figure 5: The overall deformation and tectonic map of Lake Van show the correlative structural relations; EB: External basin, IB: Internal basin; CSZ: Carpanak spur zone, SLBB:sub lacustrine basement block, SR: Sedimentary ridge on this mape (Toker et al., 2017). Lake Van forms a down-dropped, asymmetrical fault bounded Quaternary pull-apart basin. Magmatic intrusions take place around deep central Tatvan Basin which represents cauldron subsidence.

They interpret these folds to be anticlinal features with varying amplitudes associated with strike-slip faulting. Based on the observation and analysis of seismic reflection data, they found that a major element involved in the basin formation of Lake Van is strike-slip deformation and sedimentation. Subbasins of Lake Van appear as a small pull-apart boundaries formed by normal oblique faults (Toker et al., 2017).

Kempe and Degens, 1978, claimed that Lake Van belongs belongs morphologically, to the group of rift lakes, which are situated at the margins of crustal plates that is between Bitlis Massive and Eastern Anatolian Accretionary Complex. This is a strange result for lakes that developed in collisional settings.

Çukur et al., 2014, stated that during basin development, extension and subsidence alternated with compressional periods, particularly between ~340 and 290 ka and sometime before ~14 ka, when normal fault movements reversed and gentle anticlines formed as a result of inversion. Tectonic activity, highlighted by extensional and/or compressional faults across the basin margins, probably also affected the lake level of Lake Van in the past.

The Tatvan Basin with steep boundary faults, the basin morphology and the lower-lying basement (Figure1, 2) suggests that it is undergoing a gradual, continuous subsidence at least 100m in total magnitude that is still active today (Degens et al., 1978). This process could have been gradual and continuous, but could also have been episodic. The underlying cause may reside in the repeated partial emptying and gradual collapse of the magma chamber that feeds the Nemrut Volcano. The fact that over $210km^3$ of volcanic material have been extruded from this volcano while only about $50km^3$ of additional lake volume has been created by subsidence makes this concept physically admissible. Sonobuoy data indicate a foundering rate of the order of several mm/yr, so that the corresponding rate of the lake level change must be similar. Tatvan Basin flatness is due to a thick blanketing of sediments, which have mantled stratifications that exibit considerable more relief. Thus, subsidence gives rise to slow lake level variations, while those caused by a water imbalance of mass flows from the lacustrine shelfs are catastrophic.

We think that Lake Van is situated at northern edge of Quaternary intracontinental strike-slip plate boundary of Muş-Zagros suture zone (Photo 1) and formed a down-dropped pull-apart central basin. It is an asymmetrical fault bounded Quaternary pull-apart basin and takes place between N-S colliding Bitlis Massive and East Anatolian Ophiolitic Accretionary Complex (Figure 5). The ring fractures around the subsiding basin in seismic sections are seen as graben faults (Figure1). Magmatic fissure intrusions or ring dykes in south, west and south-east parts of Tatvan Basin are probably associated with magma plumbing into the ring fractures (Figure 5).

Tatvan Basin is a circle shaped sink structure resulting from the down dropping along a steep ring fractures of a more or less cylindrical block with 17km diameter. This downdropping developed within basal granitoitic Bitlis Massive reaching into the magma chamber. indicate that magma plumbing systems occur beneath calderas (cauldron subsidence structures) and Cuney, 2014; describes the cauldron subsidence process as fundamental source for uranium mineralisation (Figure 4). In Tatvan Basin and World's jargest Streltsovskoye caldera of Russia and Olympic Dam caldera of Australia have ascending hydrothermal fluids which appear to have transported U to the site of deposition and leached large volumes of U-rich rock.

Photo 1: Lake Van is situated within pull-apart basin. Right-lateral Mus-Zagros fault zone was developed during Quaternary time as result of N-S compression and collision between Bitlis granitoid Massive in the south and ophiolitic accretionary complex in the north. Nemrut volcanism extruded together with the pull-apart lake development. Kirkor dome, Kale Hill dome and collapsed cones at southern part of Lake Van represent magma plumbing systems beneath Nemrut crater and Tatvan caldera which develop incrementally as magma rises, intrudes and rejuvenates (Karaoglu et al., 2005).

3. GEOCHEMISTRY

3.1 Hydrogeochemistry of the Lake Van water column

İn a study state that evaporation processes, hydrothermal activities and chemical weathering of volcanic rocks result in the extreme alkalinity of the Lake Van water (alkalinity 155 meq/L, pH 9.81, salinity 21.4 ‰ mainly of Na_2CO_3 and $NaHCO_3$) (Tomonaga et al., 2014). According to a study, there is a strong covariance between δ18O and δ13C values of the bulk carbonates (r>0.85), which demonstrates that the lake remained as a closed basin in general (Lemcke and Sturm, 1997). Recent studies from International Continental Scientific Drilling Program (ICDP) drillings showed that Nemrut volcano extruded some type of pyroclastic flow or debris avalanche which dammed across the Muş Basin, and the outflow of the lake had been blocked about 600 ka ago and Lake Van waters began to accumulate.

Natural soda lakes with high concentrations of uranium are widespread on earth, for example, Lake Van in Turkey (110µg/L), Issyk-Kul in Kyrgyzstan (30 µg/L), Mono in the USA, California (300 µg/L), Shar Burdiin in Eastern Mongolia (15000 µg/L) (Kolpakova, 2014). In Western Mongolia, lakes with concentrations of uranium as high as 3000 µg/L are also discovered. Uranium accumulation in surface groundwaters is due to their flowage through the uranium-rich rocks and their alteration. Uranium is dissolved and transported as uranyl-carbonate complexes, and then precipitates in lake sediments principally under the form of oxide or oxi-hydroxide. Amount of precipitated uranium depends on intensity of evaporation and on duration of water-rock interaction. Therefore we think that uranium depositions can surely occur within evaporatic dolomite hectorite clay levels and duration of water interactions lasted 600.000 years or during the deposition of sedimentary sequence within the Tatvan Basin.

Greatest soda lake of the World is Lake Van, has various uranium resources and probable thick sedimentary uranium thorium deposites in its Tatvan sub-basin. Its differences from the other soda lakes are as follows: 1) it is calculated that total 50.000tons of dissolved uranium element exits within lake Van waters (Yaman et al., 2011), 2) the most important and different origin of uranium – thorium elements and tritium gas in Tatvan sub-basin is mantle derived, basement surged radiogenic subaqueous hydrothermal emanations which are still active, 3) Total maximum 580m thick unconsolidated Tatvan basal sediments would probably contain some rich reserves of sedimentary authigenic uranium–thorium deposites, 4) Volume of lake Van is many times greater than Eastern and Western Mongolia soda lakes, although their uranium concentrations are higher due to actual higher surface evaporations (Yaman et al., 2011).

A group researchers indicate that dissolved U and Zr concentrations of Lake Van waters have mutual occurrence indicating hydrothermal origin (Figure 4) (Yaman et al., 2011). The concentrations of dissolved uranium in surface waters vary between 37–110 (mean 76) mg/L, zirconium between 17–78 (mean 38) mg/L, Vanadium between 20–55 mg/L and Mo between 9–17mg/L. U concentration up to 110mg/L in water samples taken from Lake Van were found to be about 100 times higher than in the Lake Hazar (max. 0.81mg/L) and about 55 times higher than in sea water. Previous analyses showed that carbonate species in Lake Van were about 65-fold enriched compared to seawater and are overwhelmingly balanced by sodium and potassium. The low Ca concentration of the surface waters may be attributed to precipitation due to high carbonate concentration (surface whiting) and alkalinity around lake Van.

That water column profiles of main ions illustrate the increase of salinity with depth (Figure 6) (Reimer et al., 2009). While some researchers indicate that U resides for a long period in dissolved forms within the saline water, giving rise to enhanced U enrichment in the more concentrated brines and the associated precipitated salt minerals (Yaman et al., 2011). The salt composition of the high pH-water keeps U soluble by the formation of hydroxyl complexes and uranyl carbonate complexes in near surface waters. Briefly, matrix of Lake Van water is responsible for the dissolved uranium concentrations as well as expected occurrences of high density uranium mineral depositions in the sediment matrix of the Tatvan Basin bottom. Rises in lake level suppresses deep-water mixing within deep Tatvan sub-basin which results in an increase in the thickness of the anoxic deepwater layer and in a corresponding decrease in the thickness of the oxic water layer, and leads to enhanced Total Organic Carbon (TOC) deposition and export (Figure 7) (Stockhecke et al., 2014).

Hydrogen sulfide content in Van Lake water at 200m depth was determined to be 265.2 ppm while at 320m depth to be 639.2 µg/g (ppm) (Ozturk et al., 2005). In the deep hypolimnion of Tatvan Basin below 300 m (Table 1) amorphous phases occur consisting principally of silica and some hydrated iron oxides and sulphides. While the organic matter content averages 2 to 4 % (Figure 6). According to a study, the pH values decrease slightly below the sediment surface, presumably due to release of carbon dioxide by decomposition of organic matter (Schhoell, 1978). We think that increasion of salinity, total alkalinity, dissolved organic carbon, phosphate and sulphate concentrations with depth indicate suitable unoxic environment for microbial productivity at the sediment-water interface in the Tatvan basement (Figure 6).

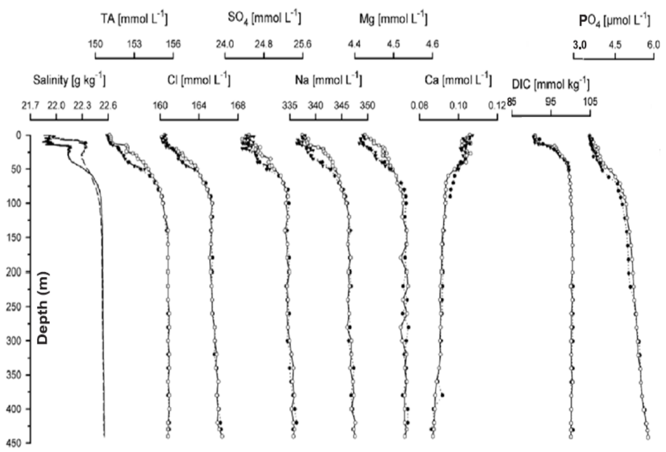

Figure 6: Depth profiles of salinity, total alkalinity (TA), dissolved inorganic carbon (DIC) and major solutes in Lake Van during June 1989 and June 1990. Salinity, conductivity-derived profiles were adjusted to calculated TDS and measured density, 1989; solid line, 1990; dashed line; total alkalinity and majors ions 1989; black circles, triangles and open circles 1990 (Reimer et al., 2009; Wuest et al., 1993). Increason of salinity, total alkalinity, dissolved inorganic carbon, phosphate and sulphate concentrations with depth indicate suitable anoxic environment for microbiol productivity at the sediment-water interface in the Tatvan Basin basement

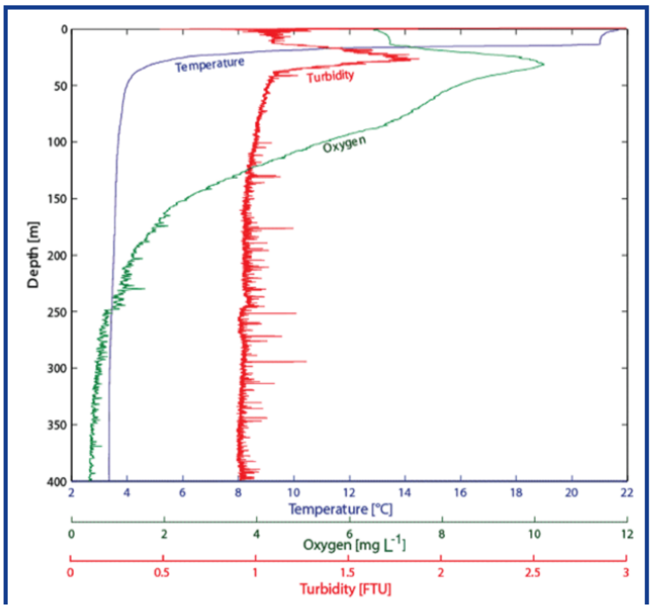

Figure 7: Temperature, turbidity and oxygen profiles acquired with a CTD probe at the Tatvan Basin mooring site on 28 August 2009 (Stockhecke et al., 2012). Note that water column temperature between 50-400m depth is 3.5 C^{o} suitable for redox changes, oxygen content between 250-400m depth is low (0.5-1mg/L) that indicates euxinic basal environment. Turbidity currents are surficial and effective down to 50m depth which doesn't affect Tatvan basement sink.

3.2 Geochemistry of basal lake sediments and pore waters of the core samples

The authigenic U formation in anoxic sediments is the most important mechanism removing U from ocean water, accounting for 40 to 70% of the riverine U input flux (Fleisher et al., 1986; Klinkkhammer and Palmer, 1991; Barnes et al., 1990). Similar uranium depositional mechanism is more valid for the lake environments which are more attainable and controlable. High lake levels are apparent in warm interstadials/interglacials and low lake levels for the cold stadials/glacials (Stockhecke et al., 2014). This pattern is reflected in TOC-rich brown laminated and TOC-poor gray bioturbated or banded sediments containing high and low Ca/K intensities respectively. The interstadial onsets can be clearly identified as increases in TOC and Ca/K in Lake Van sediments.

İn a study state that the magnesium oxide content of the Lake Van sediments is anusually high, ranging between 6 to 12 % (Degens et al., 1978). This high magnesium content is found in the authigenic mixed clay layers and hectorite. Total iron content determined as Fe_2O_3 is fairly high averaging 3%. Iron is probably presenting an amorphous state and as constituent of the clay minerals; some of it goes on account of volcanic material. The chemical environment of Lake Van dissolves and does not permit preservation of amorphous silica diatom skeletons, unless they are buried very rapidly under a protecting sediment cover (Irion, 1973; Degens et al., 1978). The silica value for Lake Van surface water is 2.25mg/l SiO_2. Rivers entering Lake Van have SiO_2 contents between 9.3 and 23 mg/l. The lowering of SiO_2 in the lake is principally accomplished by diatom populations which transfer the silica to the lake floor. On their way to the sediments, silica frustules may start to remineralise but most of the dissolution will take place at the sediment-water interface.

When the saturation limit of amorphous silica was reached in the deep basement brine, settling diatoms started to be preserved in the sediments. The Mg cycle is closely related to that of silica resulting hectorite clay formation (Figure 3) which in turn is governed by the production and dissolution of diatoms as the dominant phytoplankton species in Lake Van (Reimer et al., 2009). We think enhanced uranium enrichment and minearal deposition occurs in hectorite rich clay background of varved sediments and dolomite rich levels during desiccation phases and in TOC, Ca/K concentrated levels within sedimentary sequences (Figure 3).

4. Geophysics

İn a study stated that a seismic site survey at Lake Van was carried out several times in scientific projects and the last one was in 2009 which in total they collected fifty profiles with a total length of ~850 km by means of a high-resolution multi-channel and GeoChirp system (Litt et al., 2012). The core logging-data quality was high, and in particular natural radioactivity (natural gamma ray, K, U, Th-contents), susceptibility, and resistivity show strong variations, which are promising for further interpretations. Characterization of the physical properties of the lithologies by use of multivariate statistics (cluster analysis) and comparison with results of the core description is going on. But, until 2020 we are still waiting for the gama-ray logging-data of Tatvan Basin to be published.

A gamma ray log (Figure 8) was given in the manuscript of which was measured from the shallower Ahlat Ridge sequence where uranium mineralisation is not possible due to its oxic environment. 220m thick wireline gamma ray logging of Ahlat Ridge sequence (Litt et al., 2012) gives very weak gamma ray picks only at volcanoclastic levels while the background fine varved sediments dont give any gamma ray picks at all. This also indicates that Ahlat Ridge varved sediments have altered organic mass, thus concomitantly much lower microbial activity and no euxinic environmental characteristics for the uranium precipitation (Glombitza et al., 2013).

More detailed gamma-ray log of Ahlat Ridge sedimentary sequence is given in Figure 9 from the manuscript of which has uranium pick values around 2.25ppm (Baumgarten et al., 2015). (Baumgarten et al., 2015) while dissolved mean uranium concentration of Lake Van is 0.076ppb (Yaman et al., 2011). Therefore dissolved mean uranium concentration of Lake Van water has increased 30 times at the oxic Ahlat Ridge sedimentary bottom (Glombitza et al., 2013). We expect this uranium concentration increase within the unoxic and radiogenic flux feeded Tatvan Basin bottom sediments to be more than several thousand times that of Lake Van water.

A group researchers indicate that the largest He fluxes were found at the steep borders of the central Tatvan Basin (S1, S2, and S3 stations in Figure10) (Tomonaga et al., 2011). The terrigenic 3He/4He isotope ratio range of (2.5-4.1).10^{-6} suggests that the He entering the lake is a mixture of mantle He and radiogenic He being produced in the sediment column originating from a single, sub-continental source. A group researhcers argued that the release of He from the underlying lithosphere is fostered by fault structures that are most likely related to the ongoing subsidence of the circular main Tatvan Basin of the Lake Van and to volcanic activity (Brennwald et al., 2013).

The helium, tritium excesses were found in the water column of Lake Van, although neon concentrations were close to air saturation (Kipfer et al., 1994). The excesses of both isotopes are strictly correlated and increase with depth. In the bottom water, 4 He supersaturation is about 20% and the corresponding 3 He concentration is 2.5 times the air saturation value. The mean excess 3 He/4He ratio of 1.2 / 10^5, found in Lake Nemrut a neighbouring volcanic crater lake, is slightly higher than the Mantle Ocean-Ridge Bazalt (MORB) ratio in which a large input of mantle helium was detected. Mantle helium accounts for the majority of the helium excesses in Lake Van, although part of the 3 He excess is attributed to the presence of tritium.

The observation results of mantle tritium (3H) in Lakes Van and Nemrut, indicate that the presence of excess tritium (3H) in the lakes can be explained as material released from mantle source because of the correlation of excess 3H with mantle 3He and 4He (Jiang et al., 2008). A group researhcers indicate that the isotopic ratio of the excess helium, 3Heex/4Heex, in Lakes Nemrut, and probaly in Tatvan sub-basin was (1.032±0.006)×10^{-5} (Jiang et al., 2007). The ratios clearly indicate that large amounts of helium isotopes are released to the Nemrut and Tatvan lakes from a mantle source. The excess 3H (tritium) at the bottom of Lake Nemrut and probably that of Tatvan sub-basin, is estimated to be 3.7±1.4 TU. The correlation of the excess 3H and mantle 3He is considered and might be from a mantle source. They also concluded that the 3H (tritium) and 3He are produced by nuclear fusion (d-d reaction) in an environment (condensed matter or plasma) rich in H atoms and (U+Th) at high temperature and high pressure conditions in deep Earth.

Uranium beds are used successfully to pump, store and purify tritium gas. These properties of uranium tritide make it an excellent tritium storage and pumping material. In nuclear energy and weapons industry, tritium has more importance and value than uranium. Tritium is an important fuel for controlled nuclear fusion in both magnetic confinement and inertial confinement fusion reactor designs. Tritium can be used in a beta-voltaic device to create an atomic battery to generate electricity (rctritec.com).

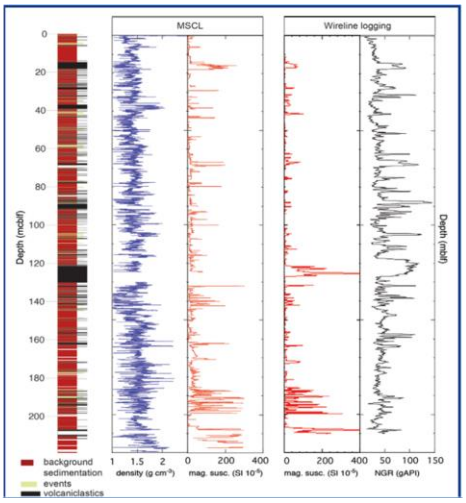

Figure 8: Simplified lithologic log of the Ahlat Ridge composite section on the basis of visual core descriptions after core openning. Dominant brown colored background sediments are laminated or banded clays, black colored layers represent volcaniclastics and light green layers represent event deposites (eg. Turbidite deposits or other mass-movement related deposits). The lithologic log is juxtaposed to multisensor core logger (MSCL), data (wet bulk density magnetic susceptibility) and on the independent logging depth scale, magnetic susceptibility and natural gamma ray (NGR) as measured by the wireline tools. Note good match between volcaniclastic layers and high magnetic susceptibility and gamma ray values. (No economical uranium pick value can be seen within Ahlat Ridge gamma ray log). Note also how wireline logging magnetic susceptibility matches MSCL data and is able to fill gaps of low core recovery. Core-based data plotted in meters composite below lake floor (mcblf), wire-line logging data in meters below lake floor (mblf) (Litt et al., 2012).

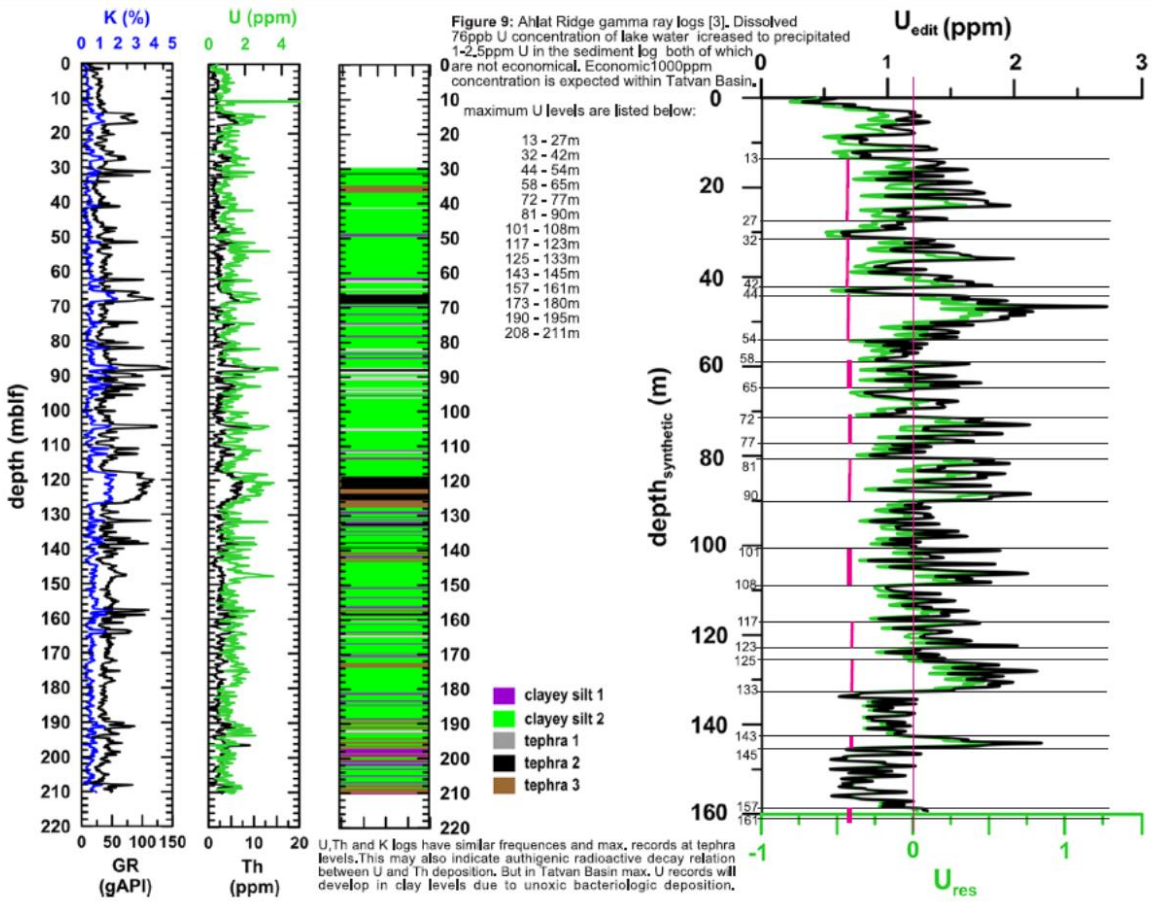

Figure 9: Ahlat Ridge gamma ray logs [3]. Dissolved 76ppb U concentration of lake water icreased to precipitated 1-2.5ppm U in the sediment log both of which are not economical. Economic1000ppm concentration is expected within Tatvan Basin.

U,Th and K logs have similar frequences and max. records at tephra levels.This may also indicate authigenic radioactive decay relation between U and Th deposition. But in Tatvan Basin max. U records will develop in clay levels due to unoxic bacteriologic deposition.

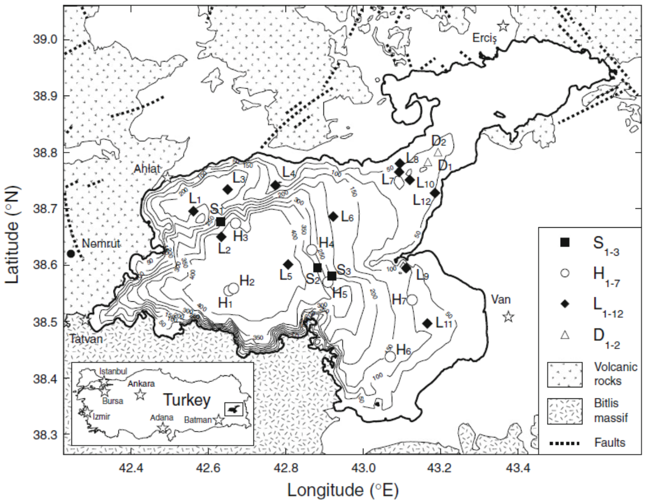

Figure 10: Geological map of Lake Van, showing the bathymetry of the lake basin and the sediment sampling sites. (L) low He fluxes. (H) high He fluxes. (S) "hot spots" with highest He fluxes. (D) noble gas concentrations showing degassing artefacts, possibly caused by bubble formation during sampling (Tomonaga et al., 2011).

We think that the excess tritium gas fluxes can be trapped and deposited within probable uraninite mineral sediments of Tatvan basement at 3Cº temperature.

5. URANIUM DEPOSITION IN ANOXIC, MICROBIAL TATVAN ENVIRONMENT

Uranium is relatively easy both to place into solution in oxidising conditions over geological time, and to precipitate out of solution in chemically reducing conditions. This chemical characteristic alone allows many geological settings to provide the required hosting conditions for uranium resources. Comprising various natural uranium resources, these incompatible environmental properties thoroughly exist within Tatvan Basin for actual uranium deposition.

A group researhcers indicate that lakes generally display higher organic productivity and sedimentation rates than oceans (Hazen et al., 2009). The most recent phase of uranium mineral evolution coincided with the rise of land plants and formation of organic-rich terrestrial and shallow marine sediments. Sediment-hosted uranium ore bodies formed at redox fronts, where organic matter reduced, low-temperature, near-surface, uranyl-rich waters led to the precipitation of uraninite and coffinite. In addition, microbes mediate the precipitation of uranium minerals through active metabolism and passive adsorption. Without repeated cycles of fluid processing, uranium will never achieve local concentrations sufficient to precipitate uraninite. In the absence of microbial activity and an oxygenated atmosphere, most of the uranium minerals found on Earth today are unlikely to form. Reduction of aqueous U(VI) to U(IV) was also enhanced by the presence of aqueous sulfate. The presence of sulfate both minimizes the lag time and increases the overall rate of reduction and uranium deposition.

U ions have an affinity for organic matter and are insoluble under anoxic conditions (Schnyder et al., 2006; Rider and Kennedy, 2011; Baumgarten et al., 2015). Therefore, they are expected to be most concentrated in the carbonaceous clayey silts of Tatvan Basin since the transport, preservation and productivity of organic material and the content of humic organic matter of Lake Van eventually collect within the deepest Tatvan sink. İn a study state that, over 100 phytoplankton species have been recorded in the Lake Van including flagellates, green algae, diatoms and cyanobacteria, with predominance of the latter two (Huguet et al., 2011). Diatom frustules were identified in all spring summer and autumn trap samples, but they were less abundant in winter when fluxes were at their minimum (Stockhecke et al., 2012). With increasing temperatures in early spring, phytoplankton export productivity grew, coupled with an increase of total mass flux and organic carbon, which might be associated to enhanced nutrient input from snow melt run off.

Some researchers indicate that; in volcanic tephra sourced iron-rich euxinic environments, pyrite accumulation can occur at higher rates in both the water column and in sediments due to higher concentrations of H_2S (Reimer et al., 2009). Therefore the presence of euxinic conditions can be inferred by the ratio of pyrite-bound iron to the total iron in sediments. High ratios of pyrite-bound iron can also be used as an indicator of past euxinic conditions. Similarly, if >45% of the bio-reactive iron in sediments is pyrite-bound, then anoxic or euxinic conditions can be inferred.

According to bathymetric shape of the Tatvan sink, prevents mixing of atmospheric oxygene with deep saline water and collects partly or completely dissolved biological and chemical remains of Lake Van and forms an euxinic habitat for sulphate reducing bacteria and other micro-organisms (Figure1,2) (Degens et al., 1978). Redox potential of the basal environment is measured to be very low and between Eh = -250 and -400mV comparing to the surface waters. Redox potential strongly affects the ionic forms of many atoms and molecules which determine reactivity (precipitation) at the cold euxinic sediment-water interface of the Tatvan Basin.

A group researchers states that first economic, apparent 6033tons uranium reserve of Turkey with mean 1157ppm tenor was found at depths between 50-180m by means of 500 MTA core drillings in Central Anatolia, south of Sorgun town of Yozgat City (Ozguner, 2018). Here, uranium was primarily dissolved from Upper Cretaceous granite horst by means of oxidising underground waters and transported to the interstitial pores of the Lower Eocene sandstone deposites within the adjacent graben. Uranium was precipitated in intergranular matrix of sandstone within anoxic lignite occurring environment and developed epigenic, tabular and roll-front type uranium deposites. It will be extracted by Na_2CO_3 bearing waters through solution mining methods for yellow cake production.

Ferro-magnesian minerals are also reducing agents for precipitation of dissolved uranium. Dissolved uranium bearing waters of Lake Van in contact with the basic-intermedier volcanic rocks can precipitate uranium minerals. Magnesium and iron rich waters also precipitate the dissolved uranium. Therefore we think that the reducing agents for uranium mineralisations and precipitations in Tatvan Basin sediment-water interface consist of four different types: a) high total organic carbon and sulphate contents enhancing productivity of reducing bacteria, b) dolomite precipitations (Figure 3) deposited during low stand lake levels c) mixed-layered clays with high MgO content and hectorite clay intercalations (Figure 3), d) basic-intermedier volcanic intrusions at the Tatvan basement with high ferro-magnesian mineral content.

6. DISCUSSION

In the Lake Van literature there is no other gamma-ray log other than that of Ahlat Ridge sediments (Figures 8, 9) (Litt et al., 2012; Baumgarten et al., 2015). Thus the Ahlat Ridge gamma-ray log measurements of the drilling cores, indirectly and misleadingly try to mention about the non-existence of uranium mineralisation within Lake Van. This is not acceptable since the both mentioned gamma-ray logs were taken from the sedimentary environment in which uranium deposition is not possible. Euxinic clay background sediments of Tatvan Basin with organic mass, microbial activity, hectorite clay and dolomite deposites and high radiogenic He, H concentrations have uranium precipitating and depositing properties, but gamma-ray logs of which unfortunately have not been published yet. Therefore, single Ahlat Ridge sedimentary sequence can not represent Lake Van basin sedimentary sequences but can only be slope deposite of deep Tatvan Basin.

A researcher indicates that U and other radioactive enrichments and their continuous upward transfer from partial melting and fractional crystallisation of ultrabasic magma occur in cauldron subsidences (Figure 4) (Cuney, 2014). Therefore enterence of radioactive emanations through the encircling Tatvan Basin faults into its unoxic waters is expected and indicate the main historical source of dissolved U in Lake Van waters. The important example of uranium enrichment and reserves occurred at the base of Streltsovka caldera in Russia and Olympic Dam caldera in Australia (Chabiron et al.,2003 and Nash, 2010).

More detailed gamma-ray log of Ahlat Ridge sedimentary sequence is given in Figure 9 which has uranium pick values around 2.25ppm. Mean dissolved uranium concentration of Lake Van is 0.076ppb (Yaman et al., 2011). Therefore dissolved mean uranium concentration value of Lake Van water has increased 30 times at the oxic Ahlat Ridge sedimentary bottom (Glombitza et al., 2013) although both are not economical. But we expect this uranium concentration increase within the unoxic and radiogenic flux feeded Tatvan Basin bottom is to be economical.

Some researchers state that beside palaeoenvironmental studies, the pore space solution analyses of the drilling cores are mostly utilised for the evaluation of uranium or radiogenic materials and their historical vertical enrichments (Klinkhammer and Palmer, 1991; Barnes and Cochran, 1990). Therefore we think that more important aim for pore solution analyses of the Lake Van drilling cores can be to inspect historical uranium enrichments in the sedimentary sequences of Lake Van. In addition all the Lake Van drilling core pore water analyses have been carried out in foreign laboratories outside Turkey.

Every authigenic disentegration of U to (Th and 4He) within the sedimentary deposites of Tatvan Basin takes place during 24.000 years time so that during 600.000 years whole life of Lake Van this kind of disentegrations have repeatedly been developed which indicate some Th depositions beside uranium within sedimentary sequence and some 4He dissolutions within the pore waters of Tatvan Basin.

A study state that sulphate reducing rates were low (≤22 nmol cm^{-3} day^{-1}) compared to lakes with higher salinity and alkalinity, indicating that salinity and alkalinity are not limiting sulphate reduction in Lake Van (Glombitza et al., 2013). In Northern Basin, sulphate reducing rate is up to 10 times higher than at Ahlat Ridge. Microbial activity is higher at Northern Basin than at Ahlat Ridge (Figure 1). Thus all suggest that organic mass in Northern Basin sediments is more available for microbial utilization than at Ahlat Ridge, resulting in higher microbial activity.

The differences between the two sites with regard to pore water chemistry also support the assumption that the two basins were at least partially separated during their geologic history. During lake level low-stands a fully or partially isolated small Northern Basin (Figure 1) might have experienced longer periods of bottom water anoxia reaching quite high up in the water column just like anoxic coal seam environments. Thus, sediments in the Northern Basin contain higher amounts of less altered Organic Mass than Ahlat Ridge sediments. The thicker layer of oxic water at Ahlat Ridge might account for the higher degree of organic mass alteration and concomitantly for lower microbial activity and uranium deposition.

Since Tatvan Basin has been a steadily subsiding, deepest, euxinic environment, its sulphate reducing rate is much higher than that of the Northern Basin. We think that the microbial activity in Tatvan Basin is even much higher than that in Northern Basin. Organic mass availability for microbial utilization in Tatvan Basin sediments is even much more than in Northern Basin. We also think that during the low-stands of Lake Van, Tatvan Basin might have experienced much longer periods of evaporite deposition and bottom water anoxia than Northern Basin in the water column. We also think that sediments in Tatvan Basin contain much higher amounts of unaltered organic mass than the Northern Basin. According to some study there had been no oxic water layer in Tatvan Basin floor (Reimer et al., 2009; Degens et al., 1978).

7. Conclusions and Reccomendations

(i) Calculated total actual existence of 50.000tons of dissolved uranium with mean 76ppb concentration and its increasion with depth and ultimate deposition within euxinic Tatvan Basin are expected to be a continuous process and to occur during geologic history of the Lake Van. It is a geological rule that today's geological processes have been repeating during the geological history. Therefore, we expect many uraninite depositional levels occur within Tatvan Basin's sedimentary sequence since the same uranium resources and the same lake water bearing U dissolving $NaHCO_3$ agent and the same reducing, U precipitating sink environment have been existing through its history. Thus, Tatvan Basin has been a natural uranium-thorium trap during its history and exploration of the possible greatest uranium-thorium reserve of Turkey will be easy since its location is known.

(ii) Three kinds of fertile uranium resources underneath the Worlds' greatest soda Lake Van appear to reflect the juxtaposition. They are; 1) steadily collapsing glassy peralkaline rhyolitic magma chamber sink of Nemrut volcano forms Tatvan Basin (i.e. cauldron subsidence with highly reducing depositional properties), 2) sub-aqueous extrusions of 3He, 4He, tritium gases and hydrothermal fluid fluxes with uranium-thorium of mantle origin from circular cauldron subsidence bounding faults of Tatvan Basin, 3) underlying alkaline gneisses and granitoids of Bitlis Massive basement bearing uranium mineralization. These resources constitute similar kind and actual version of the largest Russian uranium district of Late Jurassic Streltsovka caldera and uranium district of Olympic Dam caldera in Australia.

(iii) The 4He and 3He concentrations in Lakes Nemrut and (Tatvan Basin), were determined to be 25 and 190 times larger than the atmospheric saturation value. The isotopic ratio of the excess helium, 3Heex/4Heex, in lake Nemrut and (Tatvan Basin) was $(1.032\pm0.006)\times10^{-5}$. The ratios clearly indicate that large amounts of helium isotopes are released to the lake Nemrut and (Tatvan Basin) from mantle sources.

(iv) Uranium deposition within Tatvan Basin is caused by 1) organic mass rich levels with reducing microbial activities, 2) dolomite deposition during low stand lake levels 3) varved, mixed-layered clays with high MgO contents, 4) sub-aqueous, basic-intermediate volcanic basement intrusions 5) very low redox potential measured in the actual basal environment, 6) high density property of U minerals.

(v) State that the laminated lacustrine sediments of Tatvan Basin have high porocity varying between 40-60 % with an average 52%. The thickness of the layering and the lack of disturbances in the laminations suggest that scarcely any compaction has taken place in these sediments. In case that economical reserve of U-Th mineralisation is determined, transportation of unconsolidated sludge type uranium mineral deposites of Tatvan Basin from 450m depth to the synthetic pools at Lake Van shores by means of compressors will be easy and costless.

(vi) Application of sorption methods in uranium hydrometallurgy can be used for the extraction of uranium from unconsolidated sludge type lake sediments. Useful daughter component of uranium in Tatvan sedimentary deposites can be (Tritium, Vanadium, Zircon, Molibden, Lithium) and technologies existing in hydrometallurgy and halurgy can be applied for the extraction of these elements.

(vii) Before the Turkish core drillings; comparative radioactivity measurements at given quadrate coordinates within 300km^2 Tatvan Basin area can be carried out by drones or helicopters or airplanes. Thus, preferred core drilling locations from the measured radioactivity anomaly map can be determined.

(viii) If radioactivity measurements of submarine drones at 450m depth are possible the results will be more verificated.

(ix) Most realistic radioactivity measurements may be carried out by gamma ray detectors which are endurable against 450m deep water pressure. By intruding such detectors into Tatvan basal sludge at 10 or more points within Tatvan Basin and carrying out gamma ray measurements can be most decisive and short cut method. Thus, there may be needed to cooperate with countries that have related technologies for the radioactivity measurements.

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