Nuclear binding energies and abundances of isotopes in the Earth's crust or MORB - Correlation?

Agenda by Delian Jekov

1. INTRODUCTION.

Hello there. Thank you for reading in advance. The following wall of text was created with the main purpose to summarize the ongoing project step by step.

Note that I do not claim ownership of the text, so feel free to copy, use, edit and so on at your own risk. I finally managed to reach you, because last few weeks were a small hell for me. I had to finish a few tough studies. I had to meet with a few friends of mine, a geologist and two soil and rock experts, and an archeometrist . They managed to give me some advice, to add some vision to my idea and here it is now.

The offered scientific challenge seeks to find notable relation between isotope abundances in MORB and Earth's crust on one side and their binding energies on the other. Note that we study only the binding nuclei energies. Not the energy of a chemical reaction between iron and carbon for example. Thus, when we say reaction from now on we will mean nuclear reaction. For more information check section 2. There is an explanation on some adjustments on the model we made, and why we are confident in doing this.

Earth's age is well known. There are quite a few hypothesis of Earth's genesis. Some well justified. Other based on guesses. On the following paper we will be sticking to the HEARTHFIRE model and this exact paper by David Noel - **http://www.aoi.com.au/bcw/Heartfire/index.htm**.

This is innovative suggestions and the following calculations, adjustments and result readings will try to justify it or break it in pieces.

So we have set up our goal. Now to announce how to achieve it. We will be using a geochemical source. And we will stick to one of our choosing. We will use another source for binding energies on different isotopes.

The conditions at which MORB is generated let us exclude some elements. We will automatically exclude them from Earth's crust calculations too. Why?

We don't want to cripple our project, but we do not want to make it over informative and chunky at the same time. Simple data abundances of isotopes in MORB, crust and binding energies. That is our topic. Its focused on Mid-Ocean Ridge Basalt and we'll stick on it. More in section 2.

2. MODEL of THE EXPERIMENT

We agreed with the heartfire model. It's innovative. And it focuses on neutron core, superctitical fluid as mesolayer, and solid rock (parasolid) as mantle.

All hypothesis and adjustments are well explained in the article and we do not tend to quote and validate them here.

We will try to find a correlation between binding energies of all nature occurring isotopes on one side and abundance in Earth's crust / MORB on other. All results will be table formatted , then a graph on every function will be drawn. A team of nuclear scientists – two soil experts, a radioecologist and me as nuclear chemist and analyst, will try to establish any linear or degreed connection between the results.

Based on proposed structure and genesis of our planet, we will exclude gaseous and liquid isotopes. And we mean isotopes that will at the supposed 'morb' conditions will be liquid and gaseous. Why are we getting rid of such? Due to nuclear reactions taking place and unusual pressures and temperatures, fluids will tend to leave the system, moving to a lower gradient, i.e. from high to low pressures.

We declare we used Table 1,a database well explaining MORB and Continental Crust composition. The article is well build. Quotes are adequate. Algorithm works well within the expected range. We then can claim this concentrations official for the terms of this paper.

Then all that is left is to calculate the binding energies of mentioned in the above paper isotopes. Note that its element based research. We will need to convert if for every isotope, with simple math I will explain later. Because almost every element has more than one natural occurring isotope and usually one is predominant, let's say 95 % abundance, but we will focus on all.

We will use Wikipedia similar sources for information on the mixture of natural isotopes.

We will then calculate(we can find a trustful source most of the time, but I prefer the manual approach) the bingind energy using this article http://library.thinkquest.org/17940/texts/binding_energy/binding_energy.html and this simple formula

$$E_b = (Z \times m_H + N \times m_n - m_{isotope}) \times 931.5\ MeV/amu$$ where

E_b = binding energy, in MeV
Z = number of protons
m_H = mass of a hydrogen atom (1.007825 atomic mass units, or amu)
N = number of neutrons
m_n = mass of a neutron (1.008664904 amu)
$m_{isotope}$ = actual mass of the isotope
931.5 Mev/amu = the conversion factor to convert mass into energy, in units of MeV

Examples will be posted in every isotope comment section.
Upon calculating and charting concentration over binding energies, an analysis will be conducted.

3. DATA and ISOTOPE analysis

Let's take a look at the database we quoted above. It's build with around 5000 samples. The author had explained the algebra used. He has calculated percentage values for major oxides (SiO_2 or Fe_xO_y). He presents and ppm value for all trace elements. My first thoughts were that we'll need to convert these oxides to represent actual elements and isotopes. For the concentrations of trace elements – they are acceptable. With some conflicts, of course, but they will be examined with caution under 4th section.

We can calculate Si concentrations in percent for example, using mol fraction. Mol fraction is the relation between isotope (element) mass and the total molecule mass of the compound. For SiO_2 our data says 51,01 %. We will use the mode value as most common. From Mendeleev's table we get :

Atomic mass of Si = 28.08
Atomic mass of O = 15.99

Molecule mass of SiO2 = 60.06
Mol fraction of Si is 28.08 / 60.06 = 0,467

If we multiply this with the SiO2 concentration we get 23,82 % actual Si in SiO2. By similar approach we can calculate values for Ti, Al, Fe, Na, K, Ca.

TABLE 1.

Element[1]	data #	ρ_{MgO}[2]	arith. mean[3]	geom. mean[4] recom.	2s (rel)[5]	Mode 6	HOF88[7]	SUN89[8]
SiO2	4838	-0.51	50.89	**50.89**	0.001	51.04	50.45	
TiO2	4832	-0.76	1.73	**1.73**	0.017	1.84	1.615	
Al2O3	4832	0.53	14.47	**14.47**	0.004	14.69	15.255	
FeOT	4143	-0.69	10.8	**10.8**	0.007	10.14	10.426	
MgO	4876		8	**8**		8	7.576	
CaO	4832	0.7	10.95	**10.95**	0.005	11.41	11.303	
Na2O	4828	-0.55	2.78	**2.78**	0.007	2.91	2.526	
K2O	4793	-0.56	0.16	**0.16**	0.047	0.17		
87Sr/86Sr	540	0.01	0.70279	**0.70279**	0.00006	0.70303		
143Nd/144Nd	424	0.01	0.51307	**0.51307**	0.00002	0.51323		
eps(Nd)			8.5	**8.4**		11.5		
206Pb/204Pb	421	-0.16	18.458	**18.459**	0.002	18.38		
207Pb/204Pb	421	-0.1	15.518	**15.518**	0.0003	15.496		
208Pb/204Pb	421	-0.11	38.092	**38.093**	0.001	38.187		
(3He/4He)A	180	0.2	8.1	**8.1**	0.047	7.7		
U	538	-0.39	0.333	**0.138**	0.112	0.233	0.0711	
Rb	661	-0.43	3.9	**2.83**	0.116	2.98	1.262	0.56
K	4798	-0.56	1465	**1328**	0.026	1375	883.7	
Th	615	-0.44	0.508	**0.383**	0.115	0.363	0.1871	0.12
Pb	406	-0.26	2.57	**0.657**	0.075	0.662	0.489	0.3
Ba	925	-0.37	42.7	**25.9**	0.093	14.4	13.87	6.3
Sr	1218	-0.13	133	**126**	0.017	115	113.2	90
La	826	-0.57	5.87	**5.35**	0.065	4.09	3.895	2.5
Ce	816	-0.77	15.9	**15.6**	0.056	12.8	12	7.5
Nd	840	-0.82	12.3	**12.3**	0.042	10.8	11.18	7.3
Sm	987	-0.8	3.9	**3.94**	0.031	3.67	3.752	2.63
Eu	805	-0.86	1.39	**1.42**	0.028	1.35	1.335	1.02
Gd	563	-0.8	5.07	**4.99**	0.029	4.73	5.08	3.68
Dy	595	-0.8	5.84	**5.7**	0.031	5.18	6.304	4.55
Y	1049	-0.69	35.7	**36.1**	0.023	32.6	35.82	28
Er	590	-0.74	3.6	**3.46**	0.032	3.14	4.143	2.97
Yb	795	-0.71	3.53	**3.44**	0.028	3.13	3.9	3.05

Lu	378	-0.78	0.552	**0.556**	0.05	0.495	0.589	0.46
P	4533	-0.68	753	**783**	0.016	860		510
Zr	1182	-0.77	116	**118**	0.031	119	104.24	74
Hf	298	-0.84	3.41	**3.54**	0.086	2.88	2.974	2.05
Ta	478	-0.53	0.428	**0.368**	0.113	0.277	0.192	0.13
Nb	778	-0.52	6	**4.89**	0.088	6.98	3.507	2.33
Co	353	0.24	43.2	**42.2**	0.01	43.8	47.07	
Cr	799	0.78	253	**191**	0.07	255		
Cu	517	0.38	73.7	**68**	0.016	66.8	74.4	
Ni	945	0.83	91.8	**74.8**	0.04	77.4	149.5	
Sc	841	0.12	40.6	**40**	0.007	41.4	41.37	
Zn	522	-0.55	92.1	**93.1**	0.025	89.7		

1 major elements in percent, trace elements in ppm
2 correlation coefficient between concentration or ratio and ln [MgO]
3 arithmetic mean (normal density)
4 geometric mean (log-normal density)
5 2 standard deviation / (geom. mean sqrt(n))
6 2^{nd} derivative of the 4th-degree best-fit polynomial through the cumulated distribution between 10 and 90 percent is set to zero
7 N-MORB Hofmann (1988) EPSL 90, 297-314.
8 N-MORB Sun and McDonough (1989) Geol. Soc. Spec. Pub. 42, 313-345

We shortlisted some of our simple math, let's talk about isotopes.

Some of the analits are monoisotopic. If an isotope is predominant to a degree 98% plus of natural abundance, we count this element monoisotopic for the purpose of this task. Isotopes with abundance under 0.2 % are excluded on the current stage.
We think it's time to post table 2 , showing the Earth Crust composition for the targeted elements.

TABLE 2.

Element	mean mantle composition	
(ppm)	RF[a]	TM [b]
U	0.00988	0.0137
Rb	0.174	0.367
K	125	174
Th	0.0385	0.0541
Pb	0.0576	0.0917
Ba	3.75	4.79
Sr	17.6	18.1
La	0.519	0.534
Ce	1.38	1.44
Nd	1.11	1.14
Sm	0.38	0.383
Eu	0.146	0.147
Gd	0.521	0.524
Dy	0.653	0.652
Y	4.19	4.19
Er	0.425	0.425
Yb	0.429	0.427
Lu	0.0656	0.0658
P	84.2	
Zr	9.63	9.8
Hf	0.258	0.263
Ta	0.0293	0.0301
Nb	0.573	0.581
Co	106	106
Cr	2644	2643
Cu	30	29.7
Ni	1974	1974
Sc	16.2	16.1
Zn	54.9	54.8

Continental crust composition from
(a) Rudnick and Fountain (1995) Rev. Geophys., 33, 267-309.
(b) Taylor and McLennan (1995) Rev. Geophys., 33, 241-265.

We previously agreed we will use the red high-lined data. There are huge differences between abundance in crust vs. mantle such as Ni or Cr. We will leave for the geochemists to give us suggestions and theories why such a gap.
We are now to calculate abundance on each isotope of our target group. It’s a simple math – multiplying abundance of each isotope to altogether isotope concentrations.

For the isotopes of K, Na, Mg, ,Fe, Ti, Ca, Al and Si we'll get percentage values. For elements from U downwards we'll have simple ppm values.

Then we will plot isotope abundance against its binding energy.

A possible correlation will be sought in part 4.

4. DATA INTERPRETATION and FUTURE ASSETS

We are done with the calculations. We will focus on ppm or trace elements. As mentioned we will automatically exclude (for this paper, not in general, future aspects may inquire further investigation) isotopes with abundance under 0.2 % and 0.01 ppm in either crust or MORB compositions.

As you see used isotopes are huge a bulk. A single chart will not be of much use. We will make a few, more detailed, more specified. It will ease us well on the matter of correlation sought.

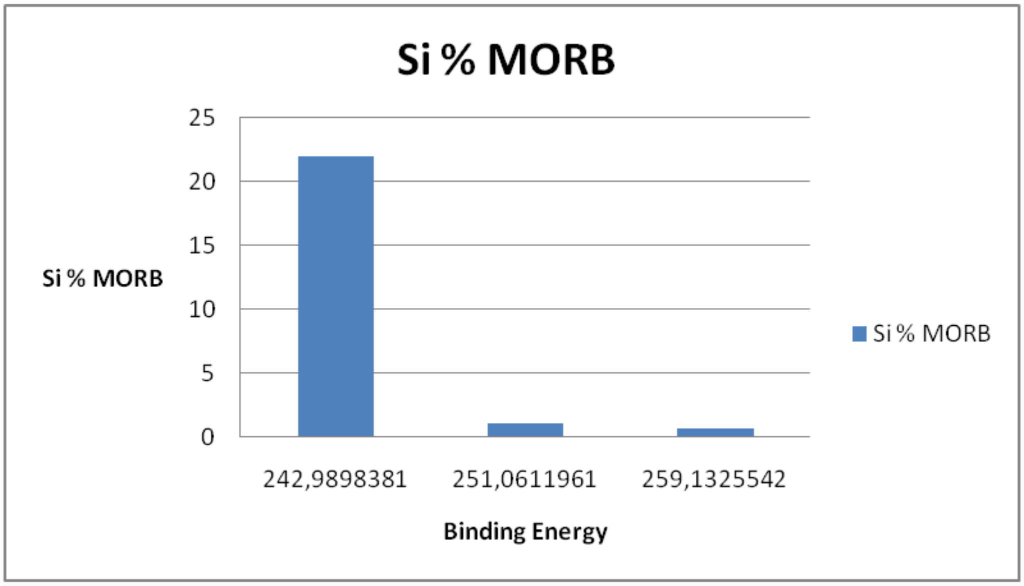
By posting to you all the data and calculations, I agree on further corrections or analysis, that's why I have left the formulas and all the data I got my hands on.

So even more and more charts and talking may be done for every isotope, for specific ones. Or a study may be needed to determine the gap between concentrations in Crust and in MORB. Some data shows differences of 3 degrees. It's either frustrating or hard to explain by the examined Hearthfire model. A study may be needed on isotopes not on this list. Or a correction on existing isotope data using different source or study.

Always we tend to ask more questions than we can answer. Only time and lots of data will help us improve the model. Or abandon it. It's open to discus.

My personal approach on the data will be to plot 4 charts. One will focus on the so called % elements, silicon for example.Second will target ppm element Zr and its abundance in MORB and Crust. Other will focus on isotopes with different abundance and similar binding energies and vice versa.

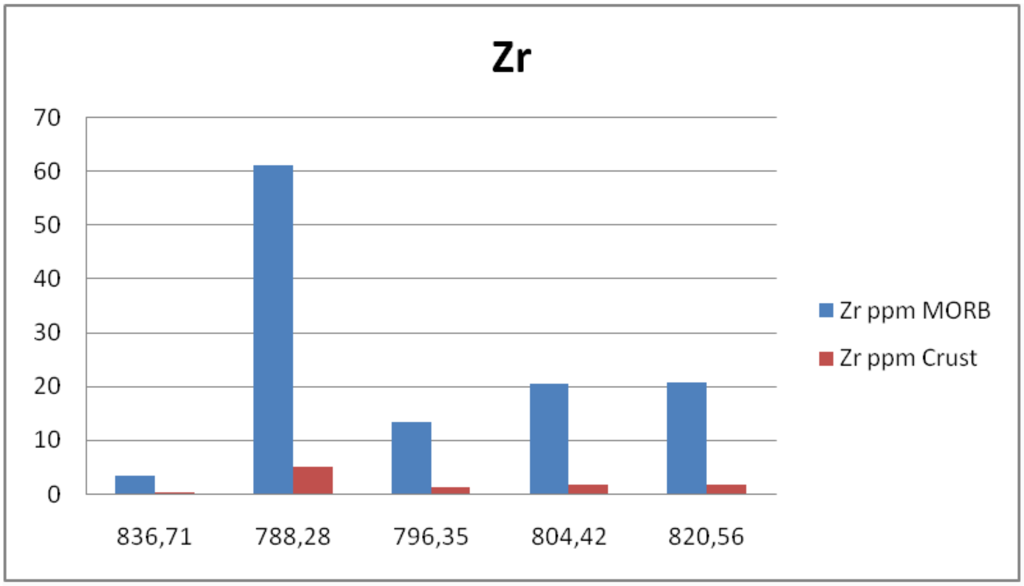
Chart 1.



It’s obvious that the most abundant isotope of nature Si is with the lowest binding energy of 242.98. Other stable isotopes are a minority.

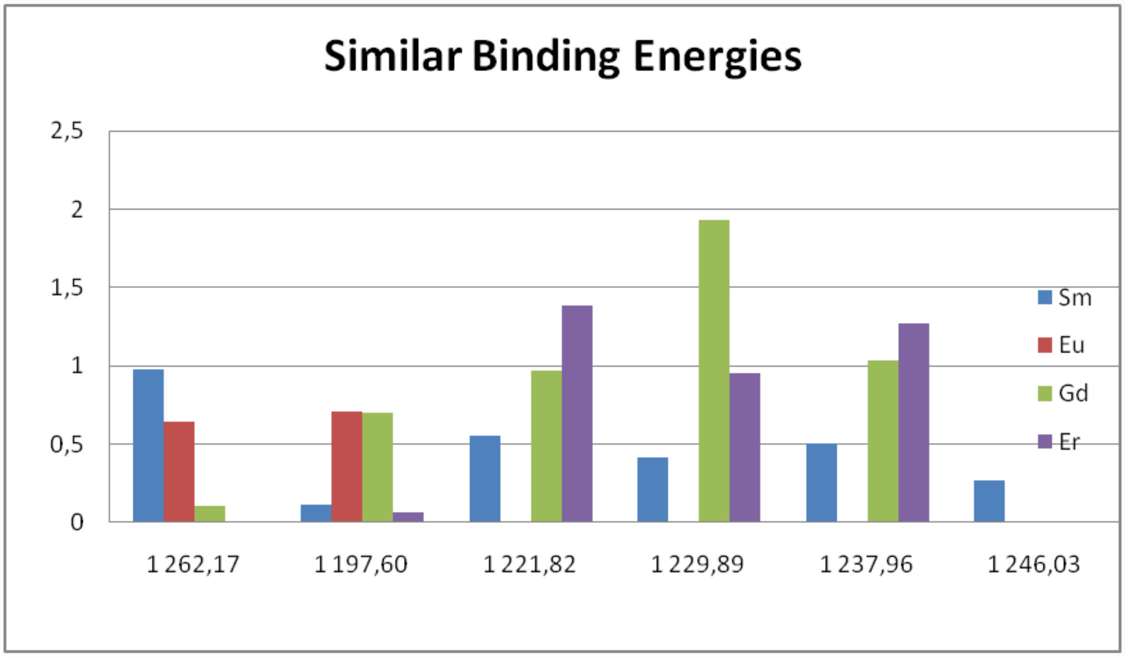
Chart 2.

Chart 3.



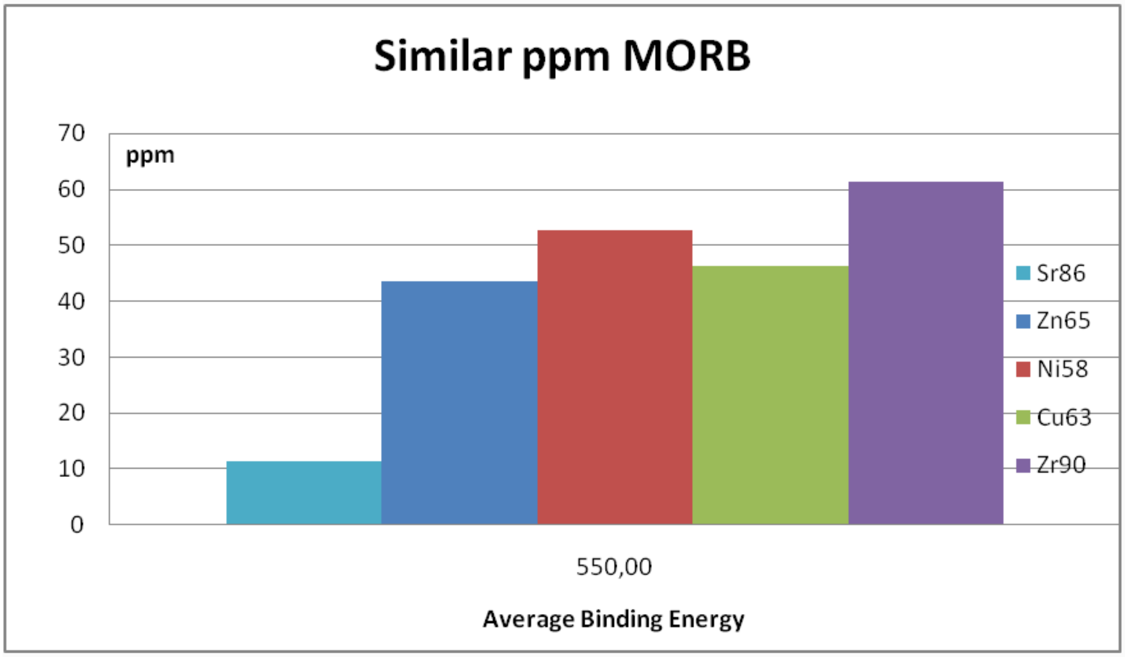
Same relation no matter the difference between Zr ppm in both samples. Easier to make isotope is most abundant. To claim that exact difference of just a few neutrons is the reason for accumulation will require more studies and confirmation of the data. Possible reason may be different nuclear genesis. Therefore different possibilities for fissure and fusion.

Chart 3.



Here we see how similar binding energy isotopes are dispersed. At 1197 for example Eu and Gd values are similar. Huge difference is observed at 1237. There is not a reliable correlation between binding energies and isotope abundance. Upper charts suggested isotopes with lowest BE must be most abundant, which in this case is false.

Chart 4.



The Sr part is at 711 MeV and is added just for comparison. On this chart we have plotted isotopes with similar abundance in ppm. Their average BEs are not that different, see the attached excel file. So there is a straight correlation in this sample. Similar binding energies lead to similar ppm values of THESE exact isotopes. If we look over other isotopes of the mentioned Ni, Fe, Cu we will see no such relation.

Overall, most abundant isotope of each presented in the study element is at most the lowest on binding energy. There is some exclusion, but the pattern persists. On the other hand there are few elements with 3-5 stable isotopes, 2 of each are similarly abundant. Not great difference observed in BE values either. This is where our model fails to explain why different neutron factor values lead to few isotopes with 20-30 % abundance.

From all examined isotopes only U and Th are radioactive. Thus they can transform with time, decaying and enriching the mantle with lower atomic weight isotopes. This will lead to a “loss” of uranium and thorium. But we know their concentrations are pretty stable within Earth’s age. There must be a source of fresh uranium, no doubt. But uranium is at the right on the BE diagram, i.e. it cannot be made on Earth, due to higher synthesis requirements. We know only elements till iron can be fusion-made on our planet. How comes then most element abundances, and isotope ones remain unchanged for the last 100 or 1000 years.

And how comes there are some Ba isotopes, radioactive, with a half life close to or exceeding Universe’s age.

Increasing binding energies does not lead to decrease in isotope abundance either. It should, if we use macrophysics and traditional science. Because we know nature always “picks” the most stable and easiest to achieve state of matter.

The answer why we have elements we can’t produce is behind the Stellar hypothesis. It suits with me. Supernova explodes and enriches the inter cosmic matter with heavier elements. Due to process being effective only for a few weeks, and very heavy pressures and high energies, many isotopes are produces. The binding energy is not an issue and dispersion is wide.

Then the Stellar comes, slowly producing heavier elements, following the BE relation, and thus achieving equilibrium in isotope abundances.

How can we transit this model into Earth? Is there a source of isotopes down there? We are about to find out.

Final notes – Hearhfire model is very elegant and innovative. I like the idea of solidifying and expanding Earth. We can explain geochemicaly why some elements are more mobile, Na >> Zn for example.

But at higher pressure and temperature in the mantle, we can’t model and predict element abundance and their mobility. It’s not a main focus on our study, but it may hide some answers.

For a better understanding I suggest similar study, even using my calculations or correct them if needed, that picks 2-3 elements with few stable isotopes with close abundances , and this to explain using nuclear genesis why least energy stable nuclei exist and are accumulated.

Until more data is collected, based on our chosen analysis, and on our calculated precise (although we found it hard to explain minus values) binding energies, we found a relation, but it is not mathematical on first view. It's not a law of x = y on z th degree. Others may find it differently.

Higher binding energies will mean harder to produce, but many such isotopes are with high abundance. The answer lies in probability of some nuclear reactions and ways to produce isotopes, different decay chains or fusion chains, S- and R-process.