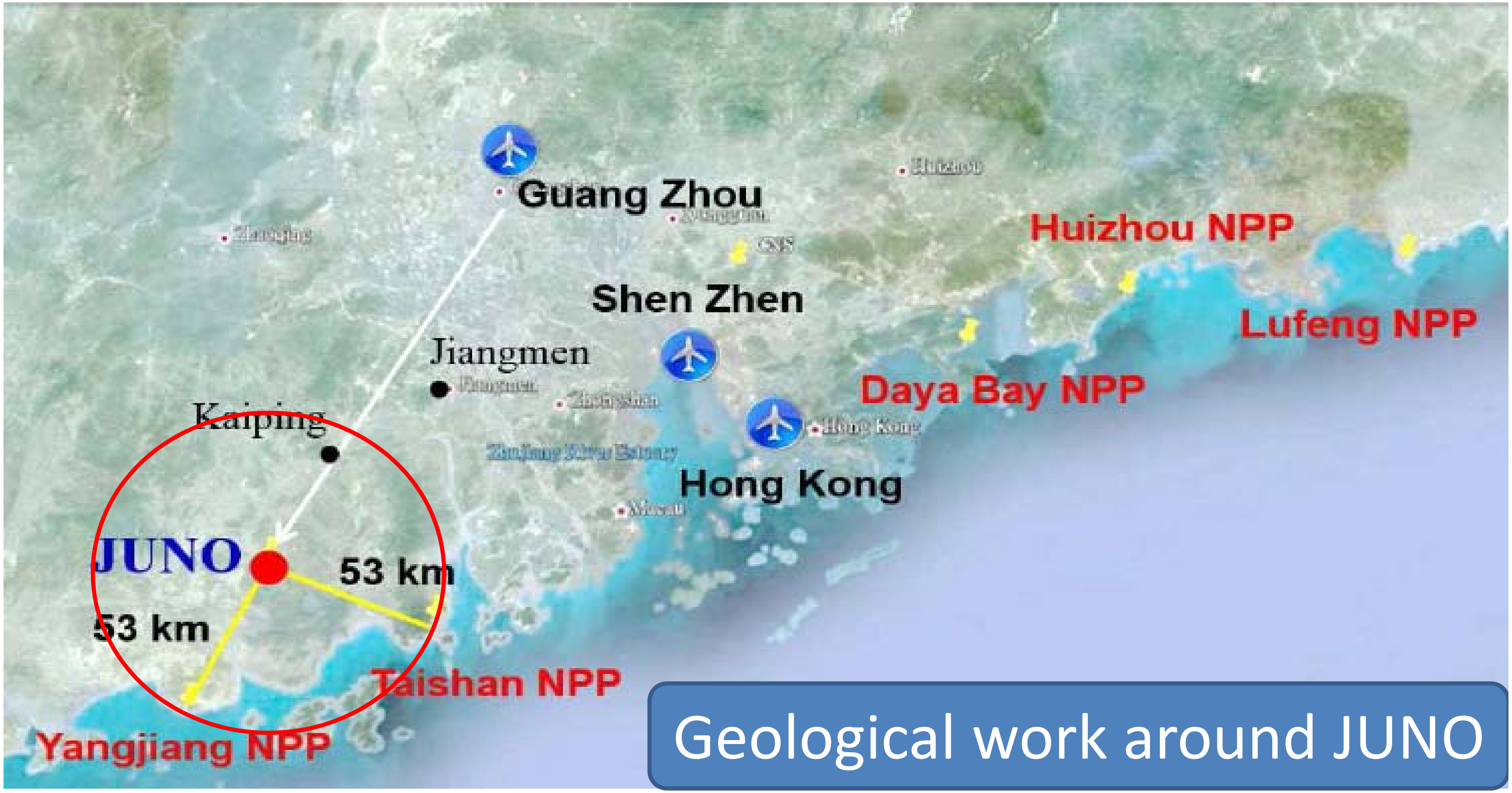

Geological work around JUNO

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Jincheng He NCEPU

Presented at workshop of Continental margin in South China: Multidisciplinary frontiers in neutrino geoscience, IHEP Beijing, 23th,July,2017

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Why we study South China?

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PART ONE

Why we study South China?

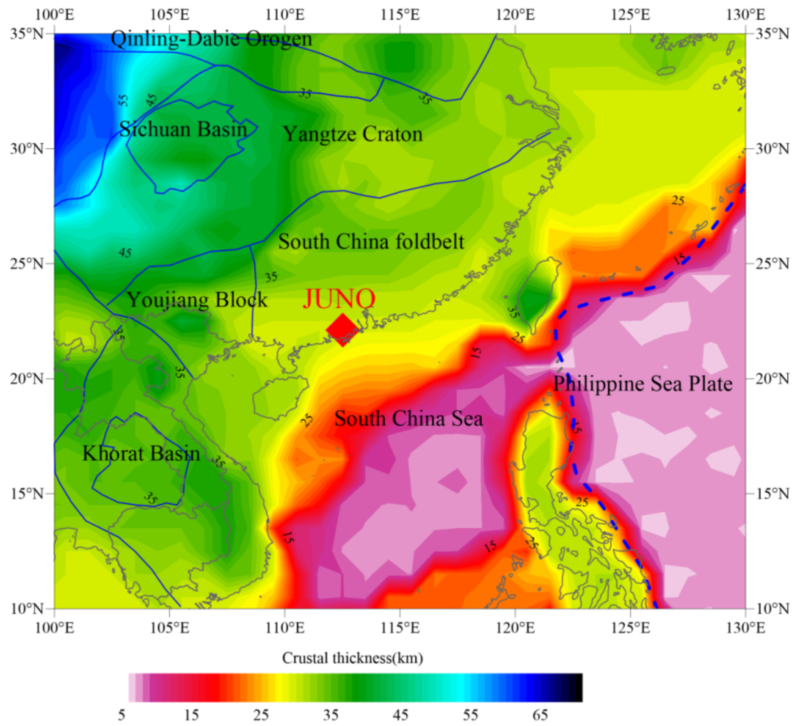
Motivation

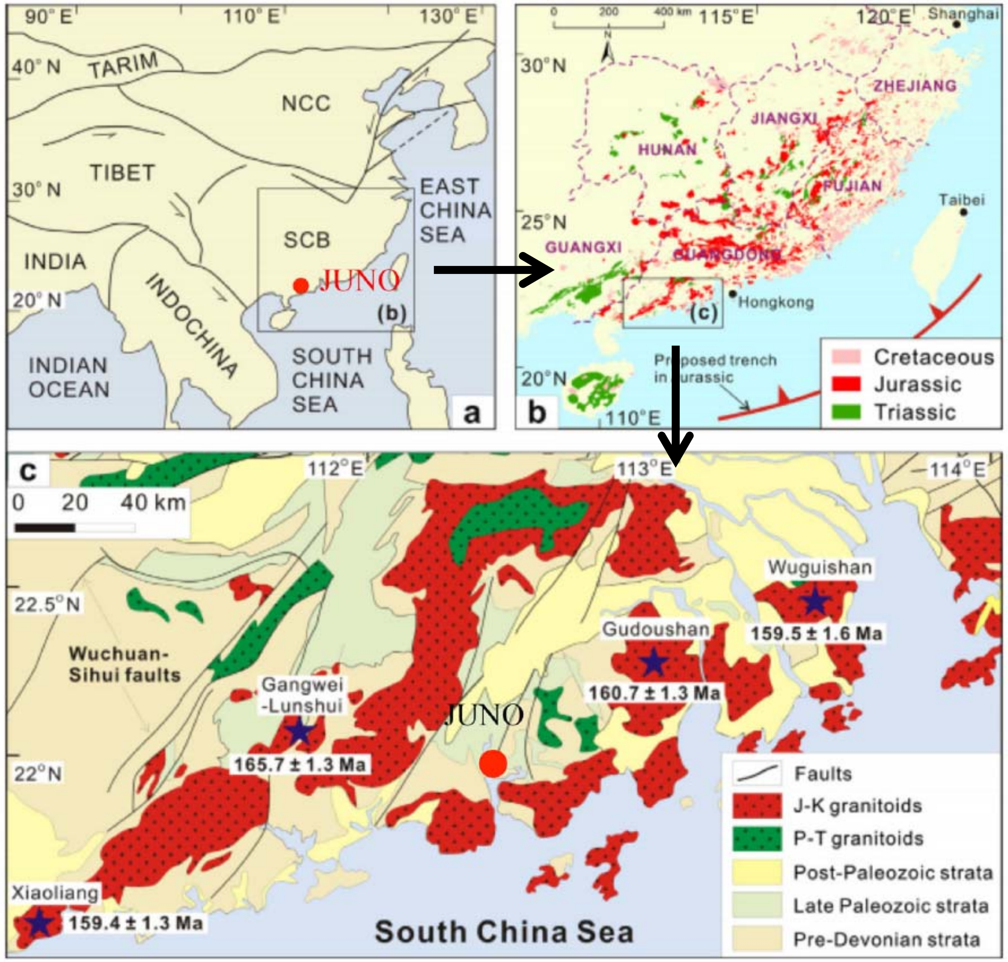
- Tectonic evolution of Cathaysia block
- Structure of and evolution of South China Sea
- Mineral resources in South China
- Geothermal resources
- Neutrino geoscience study

Motivation

- Tectonic evolution of Cathaysia block
- Structure of and evolution of South China Sea
- Mineral resources in South China
- Geothermal resources
- **Neutrino geoscience study**

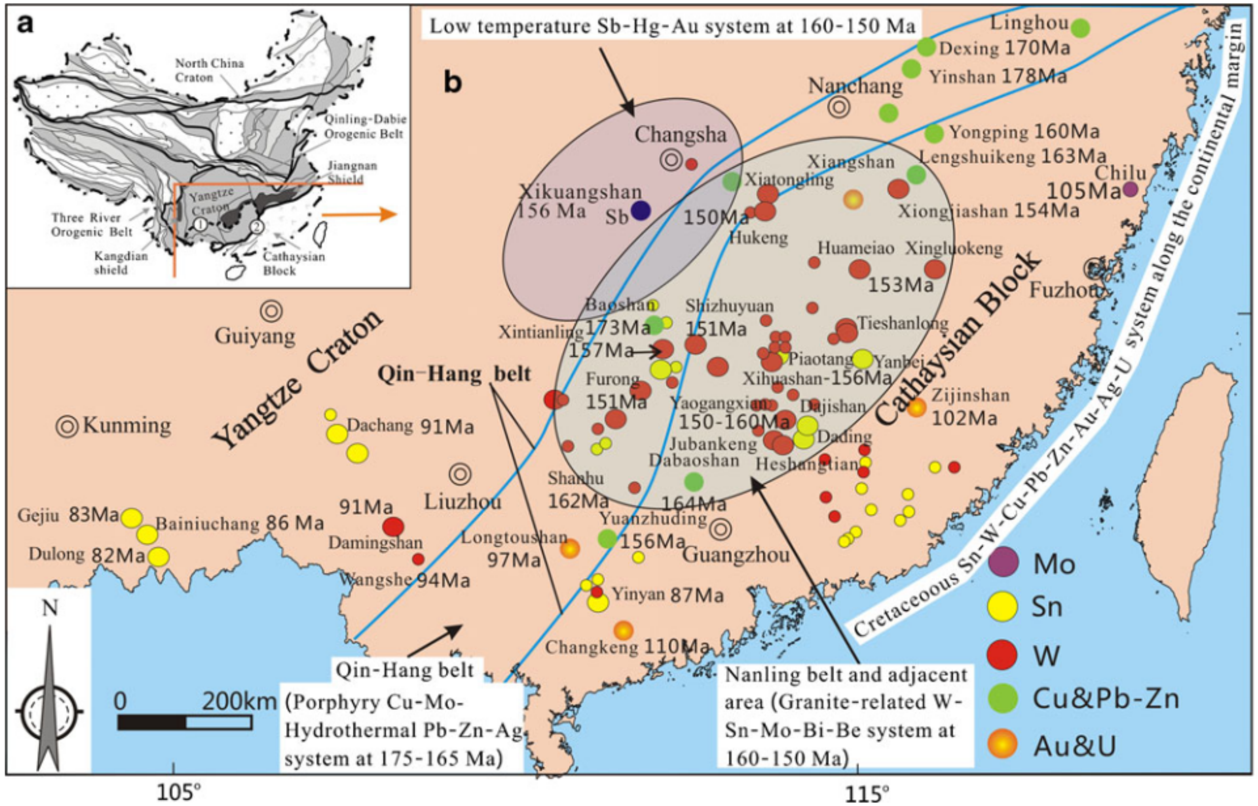
Crustal thickness from **CRUST 1.0** model



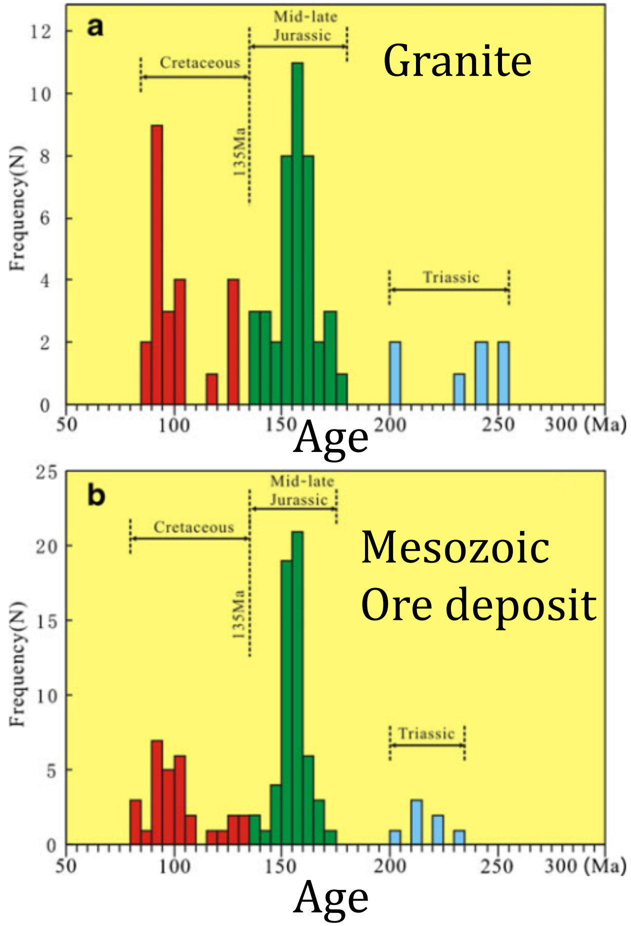


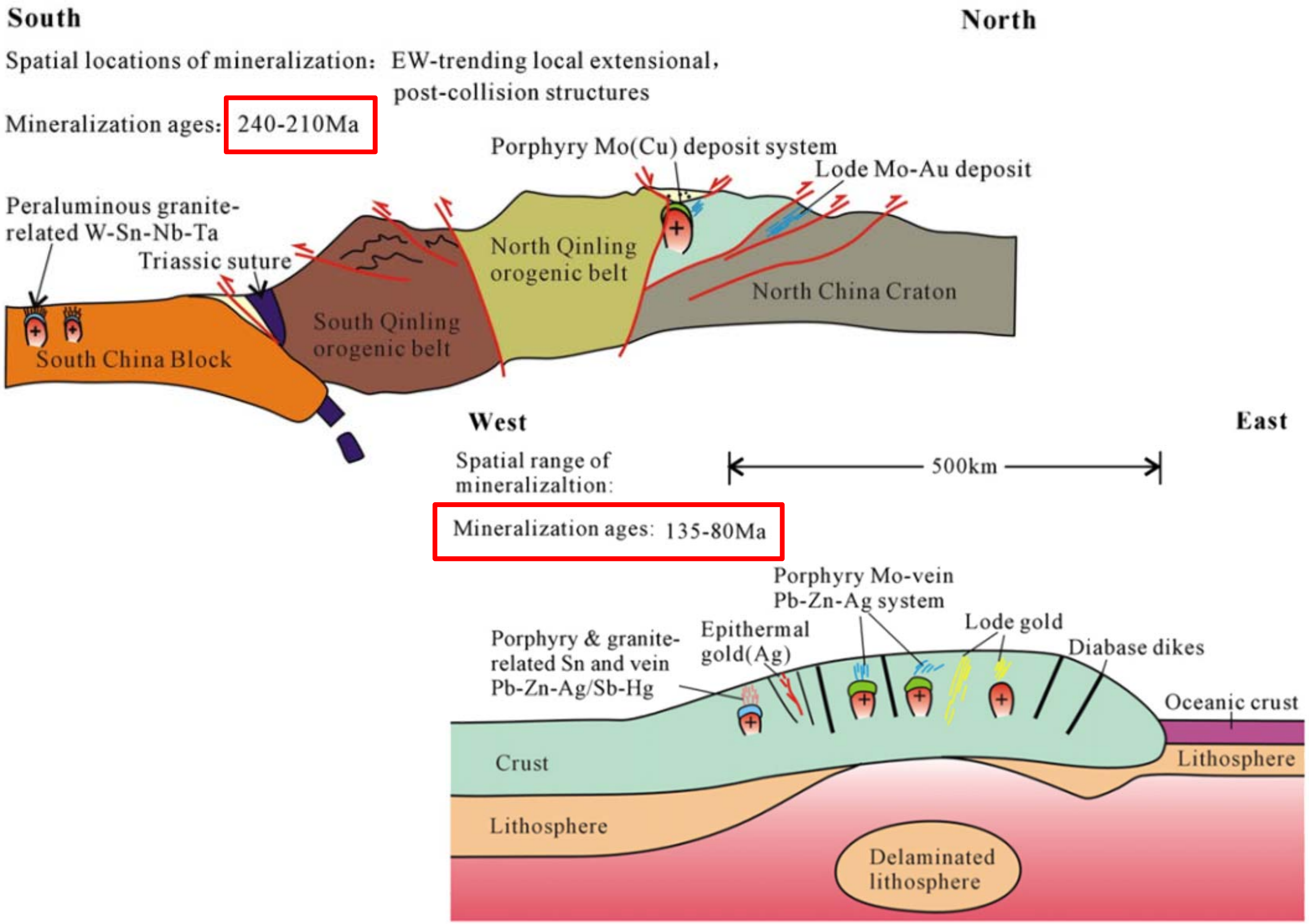
(Huang et al., 2013)

Distribution of major **Mesozoic ore deposits** in South China.



(Mao et al., 2013)





Mesozoic mineralization pulses and ore types in East China and related **geodynamic events.**
(Mao et al.,2011)

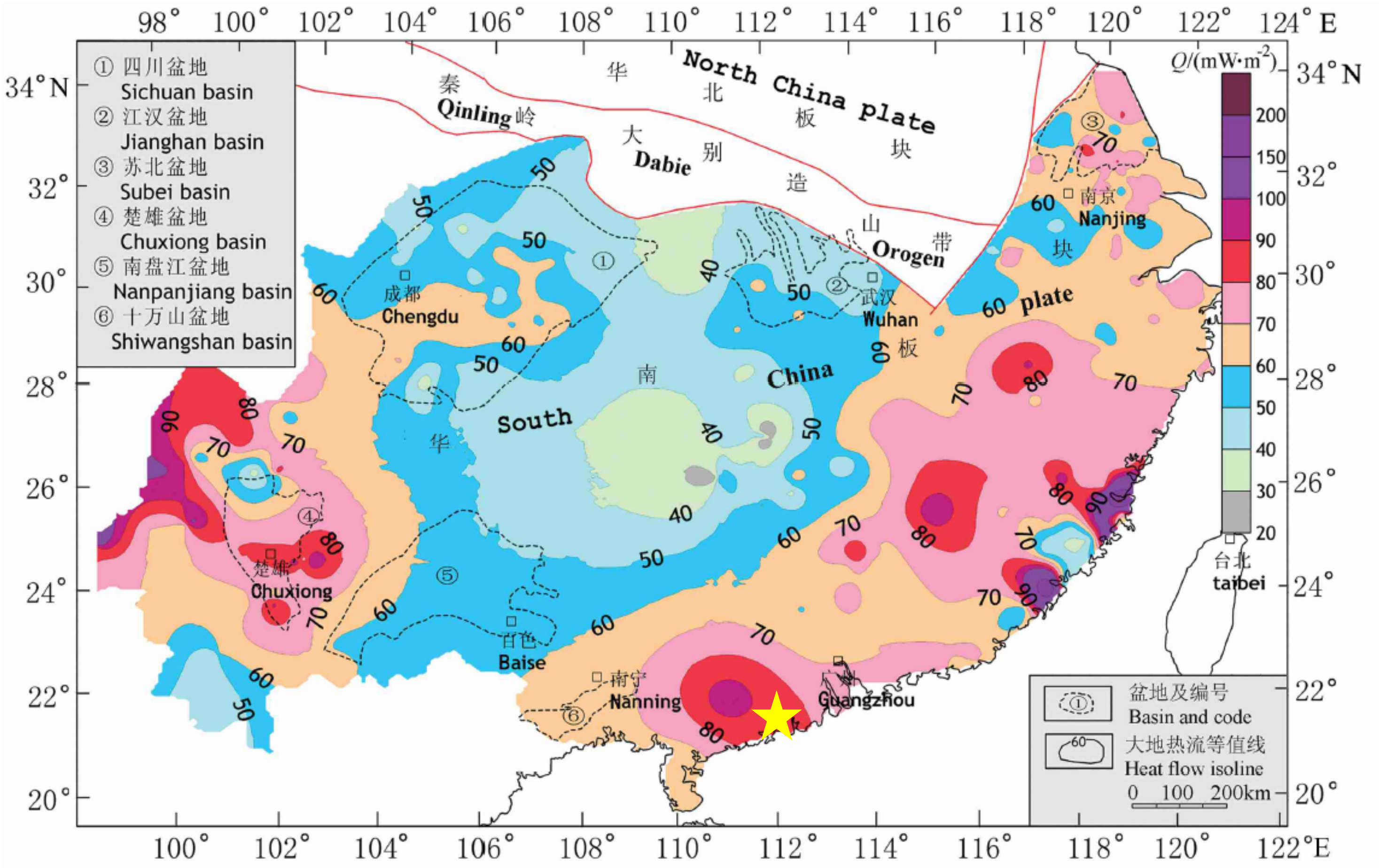
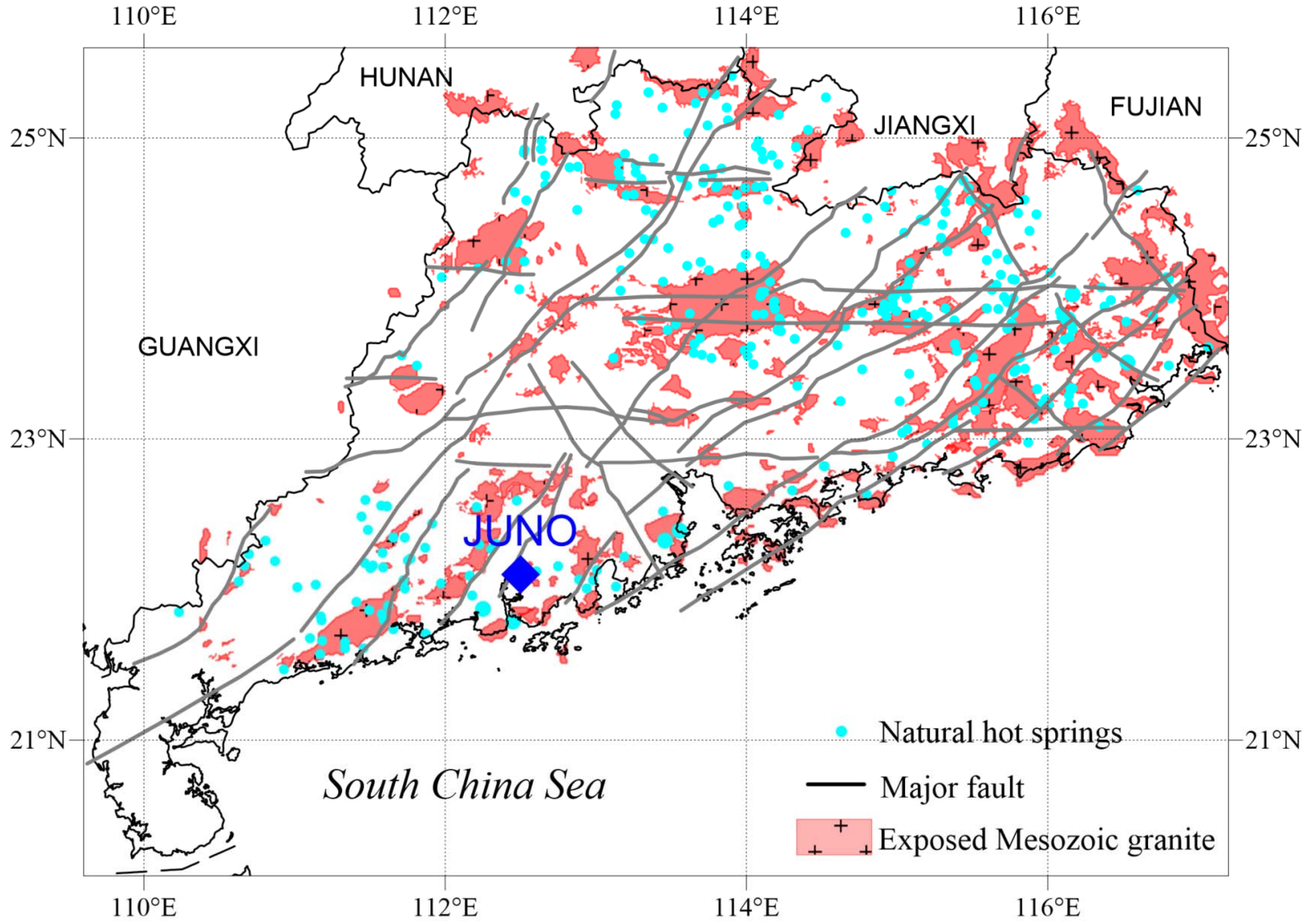


图 2 中国南方大陆大地热流图 (Yuan et al., 2006)

Fig. 2 Heat flow map of South China continent

Global continental average ≈ 65 mW/m^2



Geothermal resources around JUNO

And……

For neutrino geoscience !!!

Geoneutrino flux calculation:

Activity and number of produced geoneutrinos

Volume of source unit

$$\Phi_i = A_i \cdot n_i \cdot P_{\nu_e - \nu_e}(E_\nu, |\vec{L}|) \cdot \int_V \frac{a_i(\vec{L}) \cdot \rho_i(\vec{L})}{4\pi |\vec{L}|^2} \cdot dV$$

Survival probability function

Abundance and density of the source unit

Distance between source unit and detector

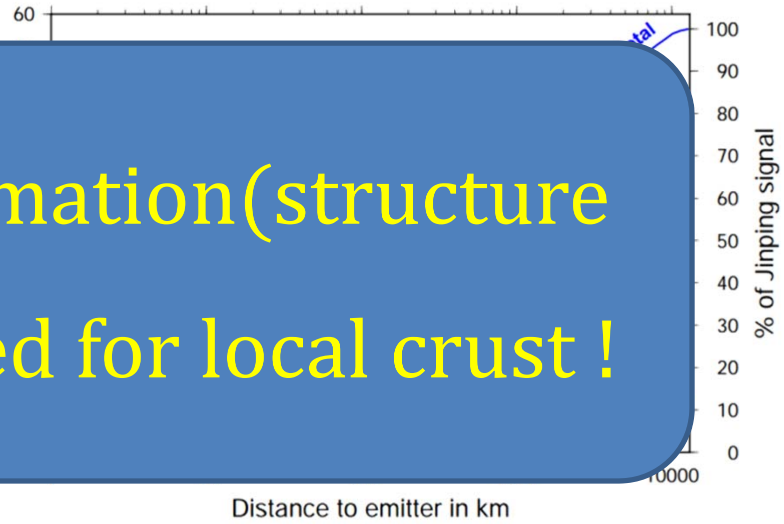
Earth structure (r and L) and chemical composition (a)

NO extra geological information(structure and composition) is added for local crust !

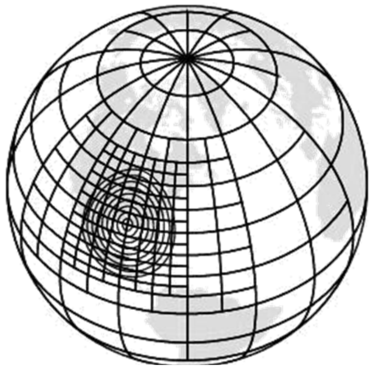
TO

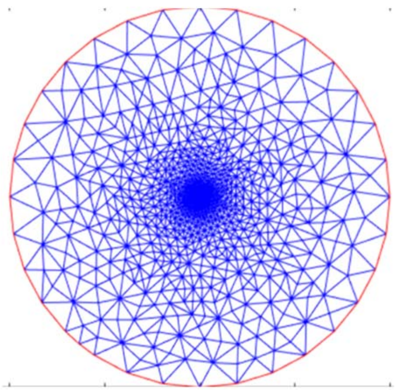
FF

M=



LOC=local crust of detector, refined grid

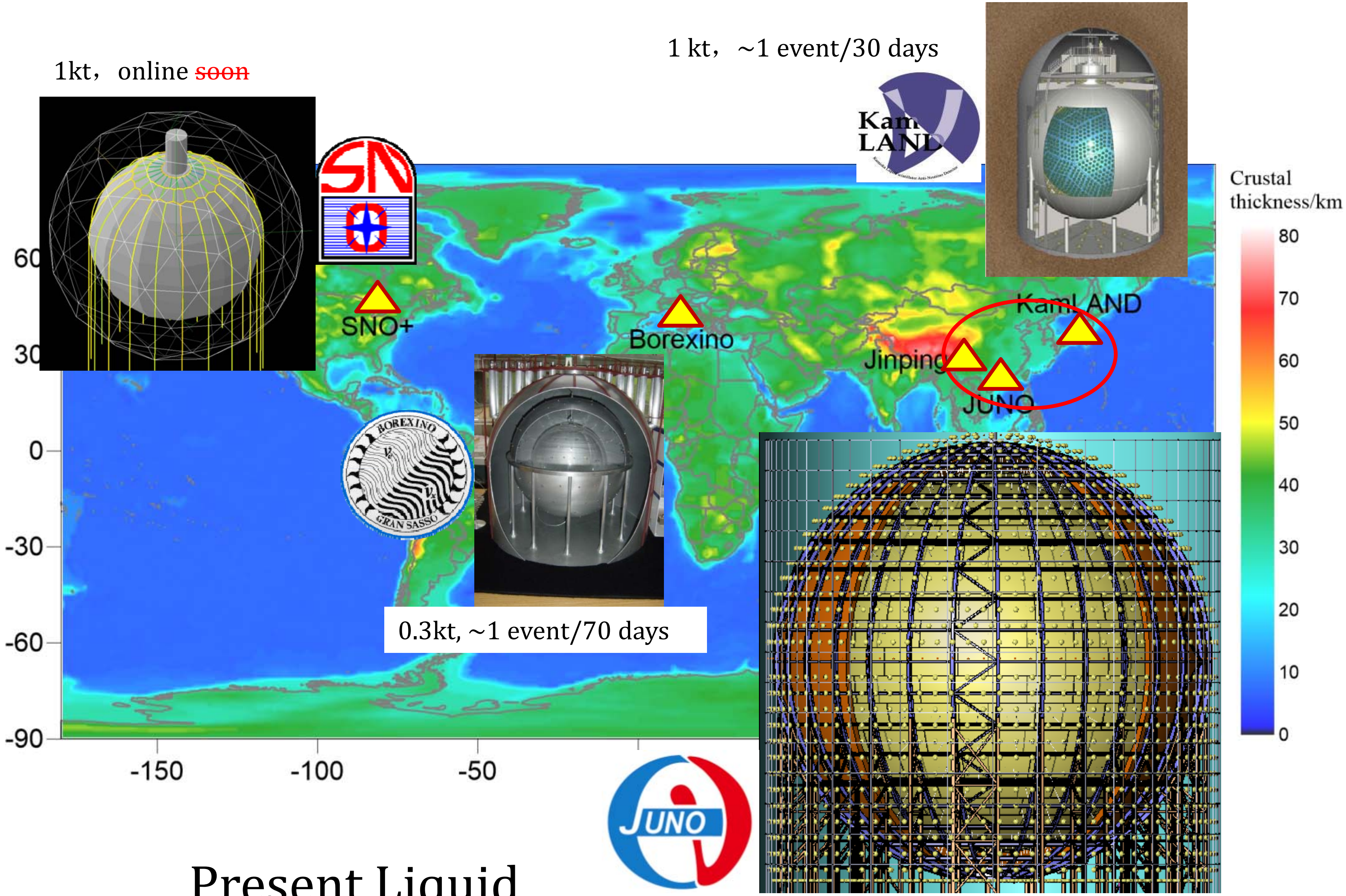




	K	Th	U
Upper CC + sediments	$(2.32 \pm 8\%) \times 10^{-2}$	$(10.5 \pm 10\%) \times 10^{-6}$	$(2.7 \pm 21\%) \times 10^{-6}$
Middle CC	$(1.91 \pm 14\%) \times 10^{-2}$	$(6.5 \pm 8\%) \times 10^{-6}$	$(1.3 \pm 31\%) \times 10^{-6}$
Lower CC	$(0.51 \pm 30\%) \times 10^{-2}$	$(1.2 \pm 30\%) \times 10^{-6}$	$(0.2 \pm 30\%) \times 10^{-6}$
OC sediments	$(1.83 \pm 7\%) \times 10^{-2}$	$(8.10 \pm 7\%) \times 10^{-6}$	$(1.73 \pm 5\%) \times 10^{-6}$
OC crust	$(716 \pm 30\%) \times 10^{-6}$	$(0.21 \pm 30\%) \times 10^{-6}$	$(0.07 \pm 30\%) \times 10^{-6}$
CLM	$315^{+432}_{-183} \times 10^{-6}$	$150^{+277}_{-97} \times 10^{-9}$	$33^{+49}_{-20} \times 10^{-9}$
Depleted Mantle	$(152 \pm 20\%) \times 10^{-6}$	$(21.9 \pm 20\%) \times 10^{-9}$	$(8.0 \pm 20\%) \times 10^{-9}$
Enriched Mantle*	$402^{+350}_{-238} \times 10^{-6}$	$147^{+74}_{-57} \times 10^{-9}$	$30^{+24}_{-18} \times 10^{-9}$
Bulk Silicate Earth	$(280 \pm 21\%) \times 10^{-6}$	$(80 \pm 15\%) \times 10^{-9}$	$(20 \pm 20\%) \times 10^{-9}$

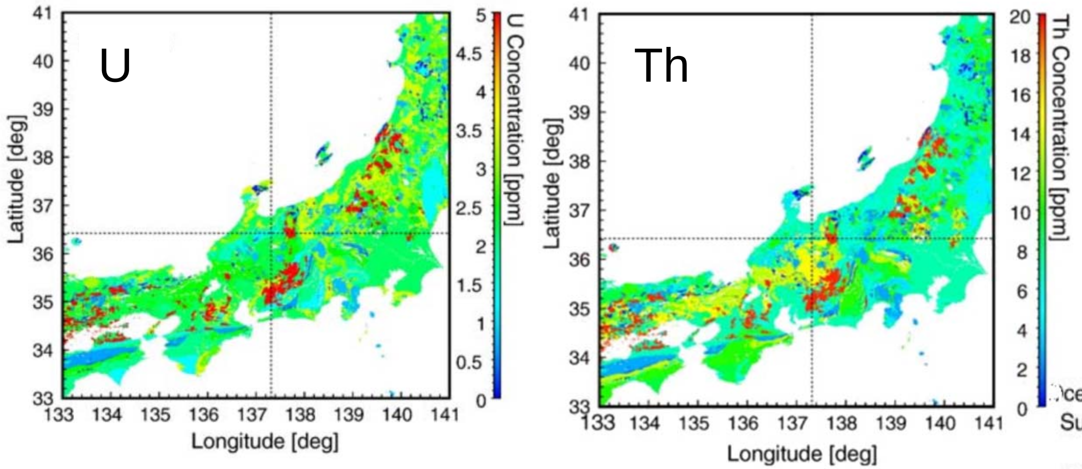
HPE abundances and the uncertainties

(Sramek et al, 2016)



Present Liquid Scintillation Detectors

Local geological work around KamLAND

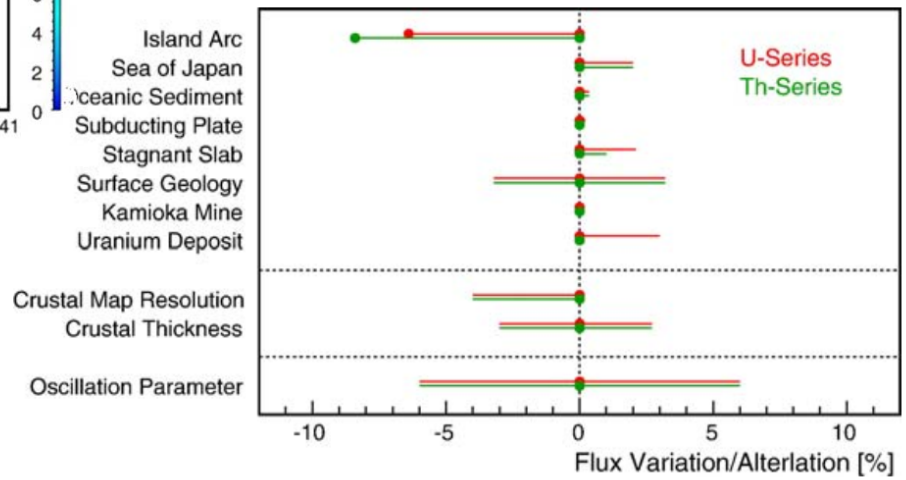


37 geological groups

166 rock samples

Assumption: surface exposed geology extend to 5 km deep

Geoneutrino flux predicted by global crustal model (Crust 2.0)



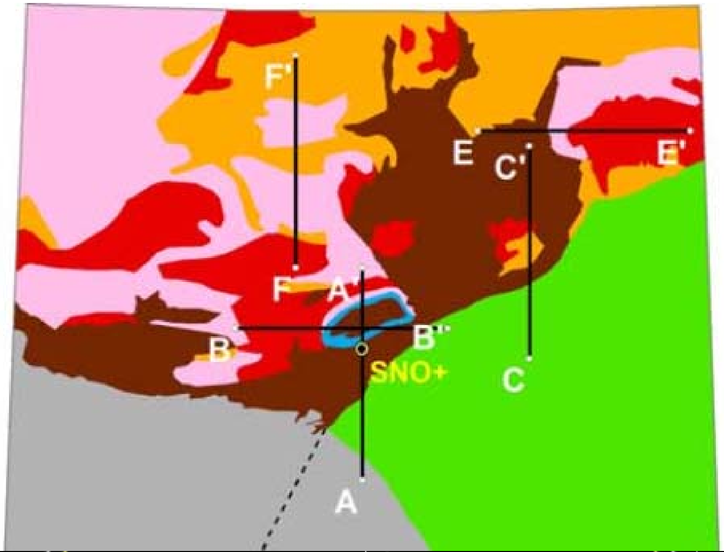
Amendment after local crust study

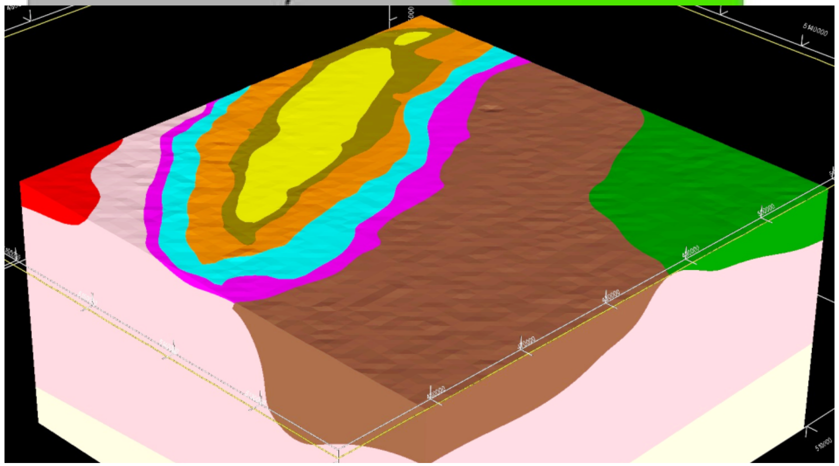
(Enomoto et al.,2007)

Local geological work around SNO+

(Huang et al.,2014)

3D model: 1km*1km*0.1km





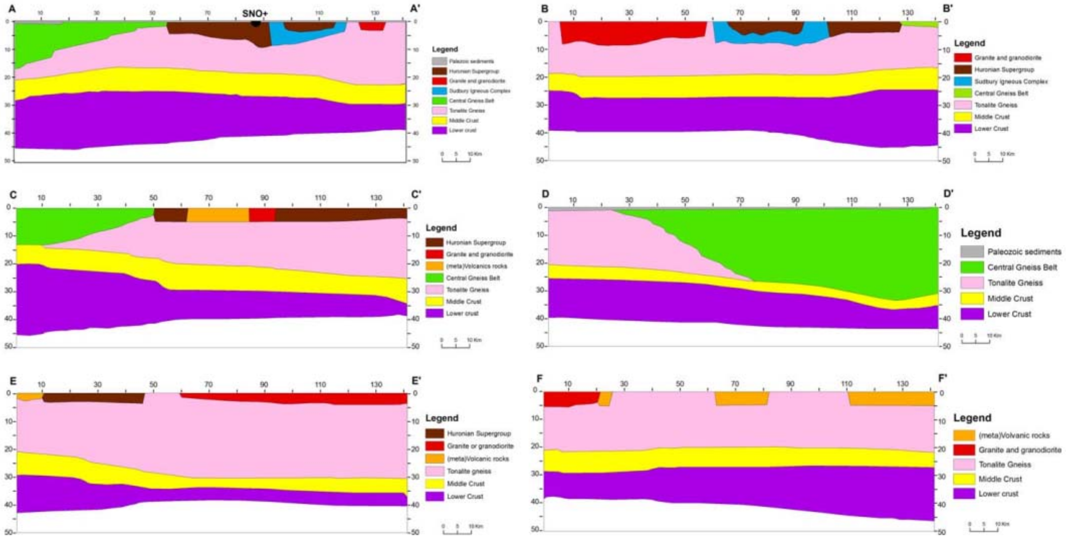
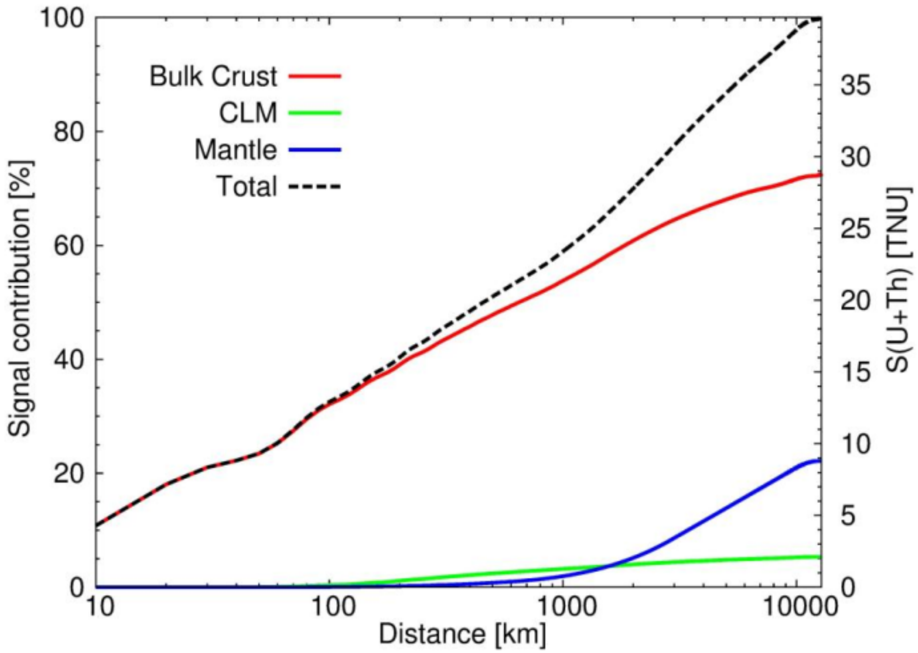


Table 6. U and Th Abundances in Seven Lithologic Units in the Regional Upper Crust in the 3-D Model

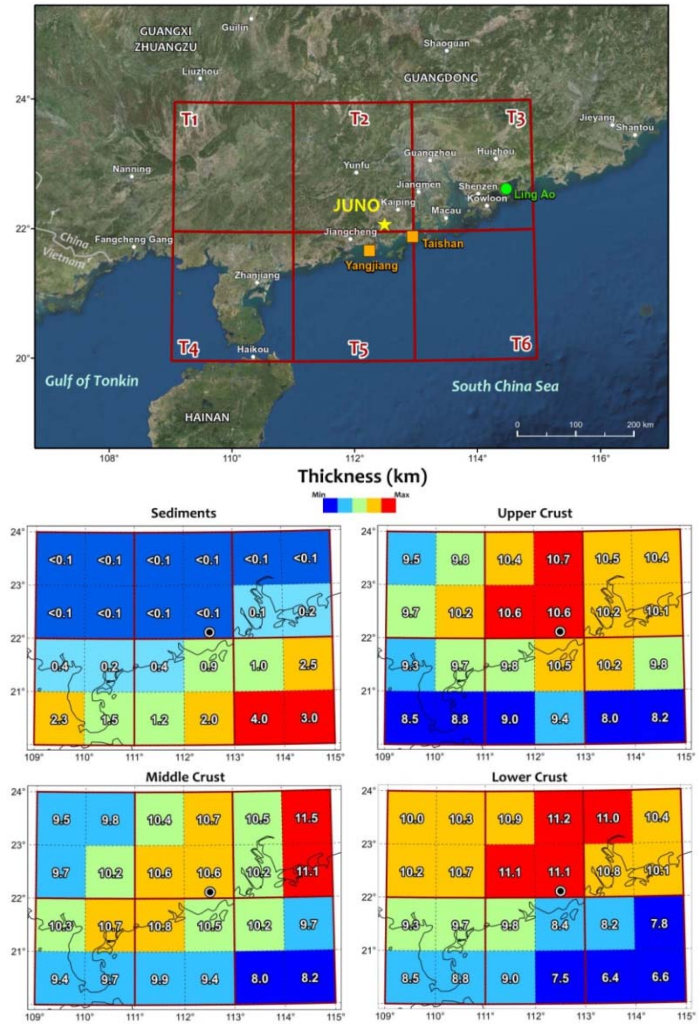
Lithologic Unit			U mean[a]	1-sigma +	1-sigma -	Median	n	Th mean[a]	1-sigma +	1-sigma -	Median	n	Correlation[b]
Tonalite/Tonalite gneiss		All	0.7	1.0	0.4	0.7	141	3.0	4.6	1.8	3.2	146	0.74
		Filtered	**0.7**	**0.5**	**0.3**	0.7	111	**3.1**	**2.3**	**1.3**	3.1	107	
Gneiss in CGB		All	2.6	0.4	0.4	2.7	5	3.9	8.9	2.7	5.3	96	–
		Filtered	**2.6**	**0.4**	**0.4**	2.7	5	**5.1**	**6.0**	**2.8**	5.9	68	
(Meta)volcanic rocks	Felsic (5%)	All	1.1	1.7	0.7	1.0	472	4.3	6.7	2.6	4.3	531	0.86
		Filtered	**1.1**	**0.8**	**0.5**	1.0	402	**4.3**	**3.0**	**1.8**	4.1	416	
	Intermediate (40%)	All	0.5	1.1	0.3	0.5	192	1.6	3.3	1.1	1.6	246	0.87
		Filtered	**0.5**	**0.4**	**0.2**	0.5	135	**1.5**	**1.3**	**0.7**	1.6	170	
	Mafic (55%)	All	0.3	0.8	0.2	0.3	333	0.9	2.4	0.6	0.8	414	0.88
		Filtered	**0.2**	**0.4**	**0.1**	0.2	249	**0.8**	**1.0**	**0.4**	0.7	316	
Paleozoic sedimentary rocks		All	3.1	5.5	2.0	2.5	10606	4.5	3.0	1.8	4.4	2196	0.55
		Filtered	**2.5**	**2.0**	**1.1**	2.3	8466	**4.4**	**1.6**	**1.2**	4.3	1700	
Felsic intrusion	Granite (60%)	All	3.9	4.1	2.0	4.1	26	24.1	26.8	12.7	28.0	25	0.60
		Filtered	**4.0**	**2.3**	**1.4**	4.1	18	**29.7**	**12.0**	**8.6**	28.9	19	
	Granodiorite (40%)	All	1.1	0.8	0.5	1.1	92	5.4	6.2	2.9	5.5	92	0.81
		Filtered	**1.2**	**0.5**	**0.3**	1.2	70	**5.2**	**3.1**	**2.0**	5.2	69	
Huronian Supergroup, Sudbury Basin		All	4.2	6.4	2.5	4.1	207	11.8	20.8	7.5	11.4	214	0.90
		Filtered	**4.2**	**2.9**	**1.7**	4.2	156	**11.1**	**8.2**	**4.8**	11.3	177	
Sudbury Igneous Complex	Norite (40%)	All	1.1	0.5	0.3	1.2	80	5.6	1.6	1.2	5.7	80	0.76
		Filtered	**1.2**	**0.2**	**0.2**	1.3	71	**5.7**	**0.7**	**0.7**	5.7	72	
	Quartz Gabbro (10%)	All	1.7	0.5	0.4	1.6	19	7.5	2.4	1.8	6.7	19	0.99
		Filtered	**1.5**	**0.2**	**0.2**	1.5	13	**6.7**	**0.9**	**0.8**	6.6	14	
	Granophyre (50%)	All	3.3	0.2	0.2	3.2	25	14.9	1.0	1.0	14.8	25	0.95
		Filtered	**3.3**	**0.1**	**0.1**	3.2	18	**15.2**	**0.7**	**0.6**	15.3	18	

Geoneutrino flux prediction with GLOBAL model at JUNO



Signal contribution with distance

Resolution: 1° *1 °
Total flux: 39.7(+6.5/-5.2)



With reference model(Huang et al, 2013)

(Strati et al., 2015)

Geoscientists should take advantage of this most-advanced experiment to help us to solve the big scientific question of the Earth (Radiogenic heat budget, bulk composition of the Earth, etc.).

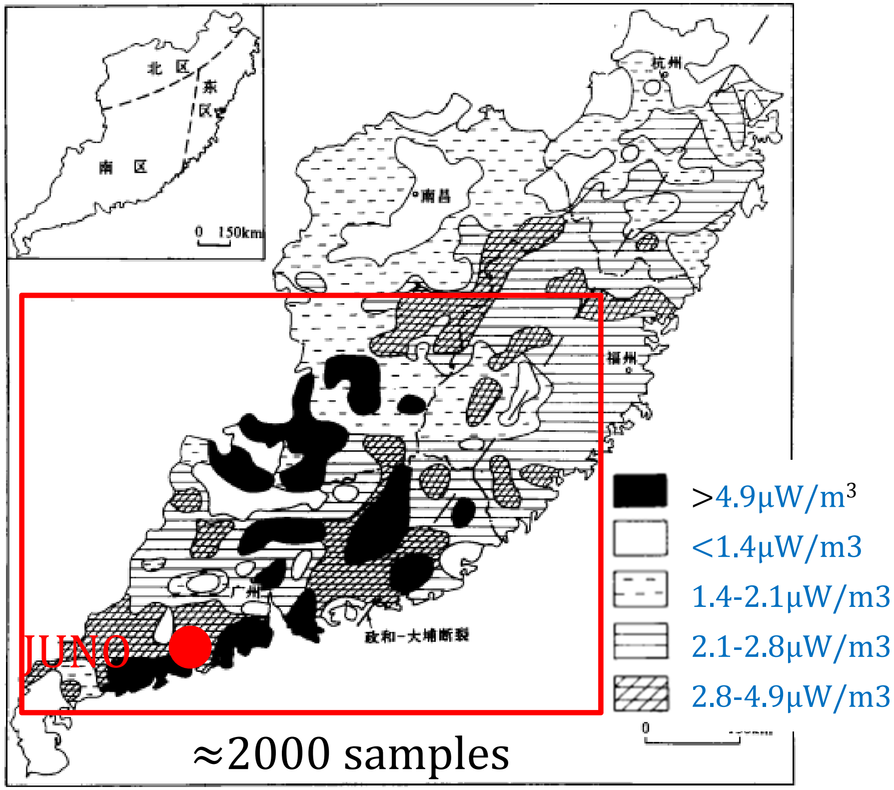
Start with local geology study !

Heat production in South China

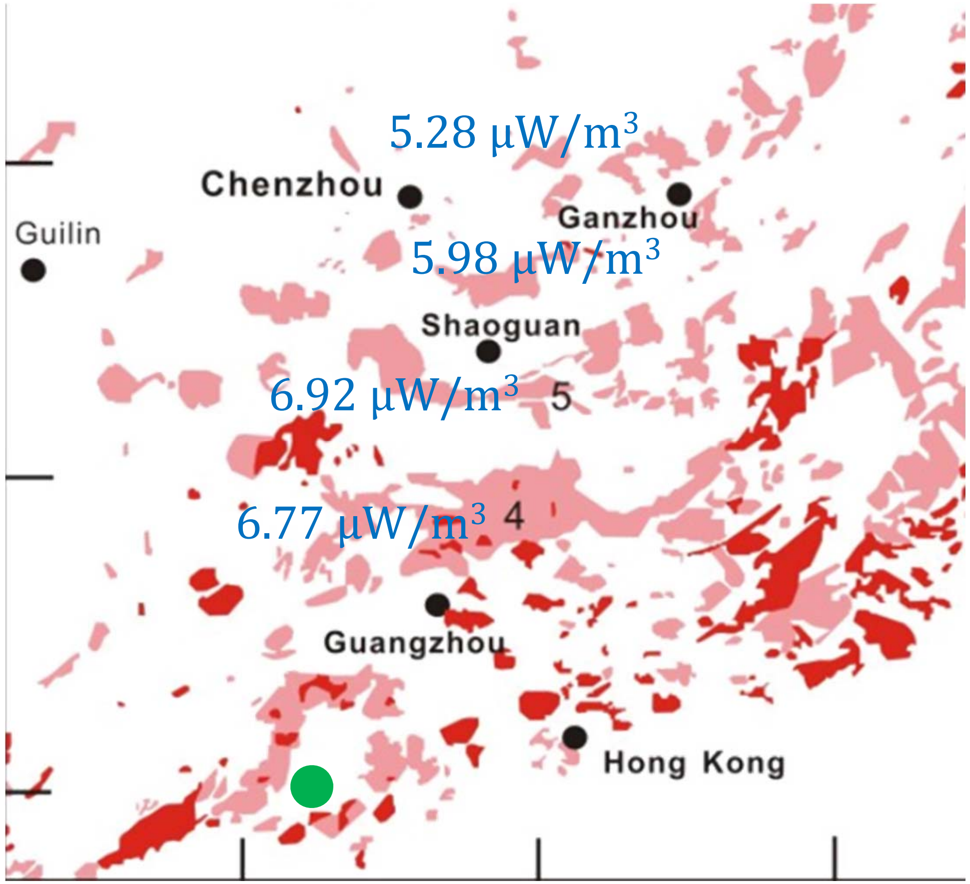
$$H=10^{-2}\rho(9.52A_U+2.56A_{Th}+3.48A_K)\ \ \mu W/m^3$$

ρ, density (g/cm^3)

A_U,A_{Th},A_K is the abundance of U(μg/g), Th(μg/g), and K(wt%),respectively.



Heat production in SE China (Zhao,1995)



(Sun et al., 2015)

Abundances of HEPs of granites in SE China (Sun et al., 2015)

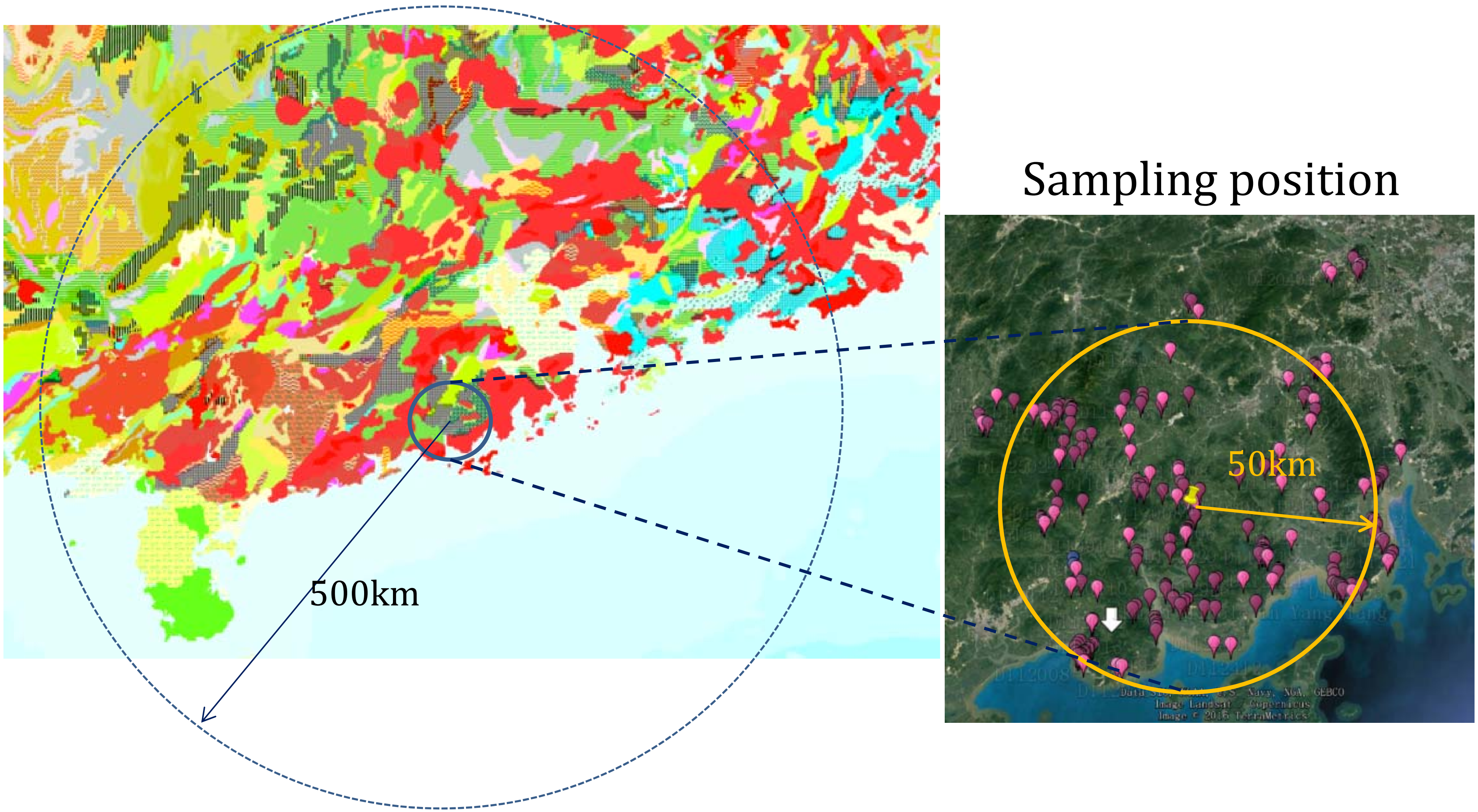
Rock Body	Sample No.	Th (ppm)	U (ppm)	Th/U	K_2O (%)	Average density	Heat production
Zhuguang	128	40	11	4.83	5.43	2.6	5.98
Guidong	4	41	9	4.08	4.02	2.61	5.28
Xiazhuang	26	31	18	2.14	5.34	2.60	6.92
Reshui	12	46	14	4.01	4.95	2.59	7.11
Fogang	37	51	11	4.96	5.12	2.57	6.77
Total	207	41	12	3.42	5.31		6.29
Global average (Rudnick & Gao,2014)		10.5	2.7	3.89	2.32	2.6	1.58

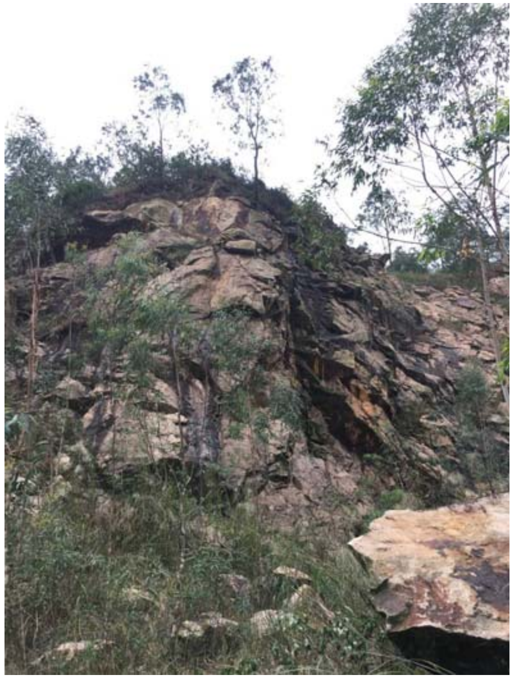
Average heat production of granites in SE China is **3.98** times of global average heat production of upper continental crust

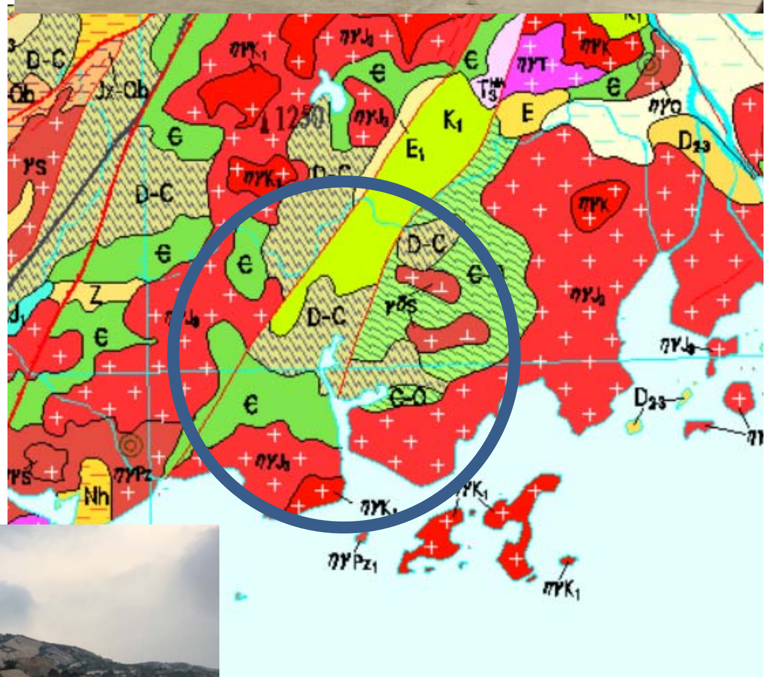
2

PART TWO

What we have done for field work?


Sampling position
500km
50km




D-C
Jx-Qb
E
D-C
Nh

Samples from outcrops

Rock Type	岩性	Number	Age
Granite	花岗岩	169	Jurassic, Triassic, Silurian, Creations
Sandstone	砂岩	80	Cambrian, Devonian, Cretaceous, Permian
Diorite	闪长岩	7	Early Jurassic , Early Silurian
Limestone	灰岩	4	Devonian
Dolomite	白云岩	2	Carboniferous
Shale	页岩	1	Late Permian
Schist	片岩	1	Neoproterozoic
Total		267	

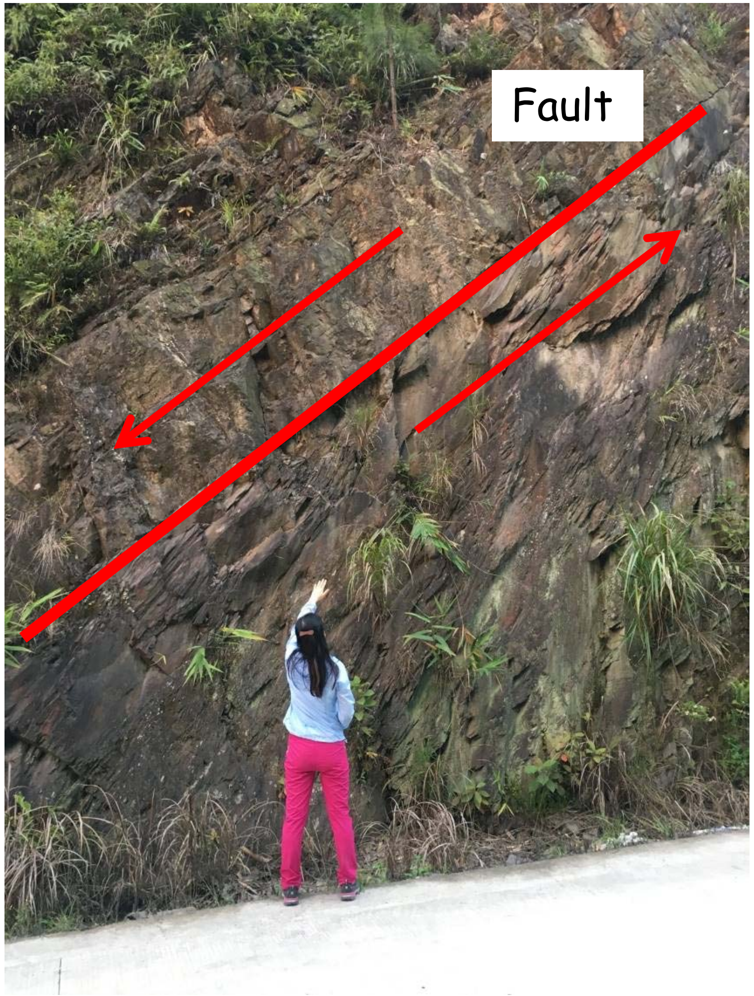
Samples from drill holes at the JUNO site

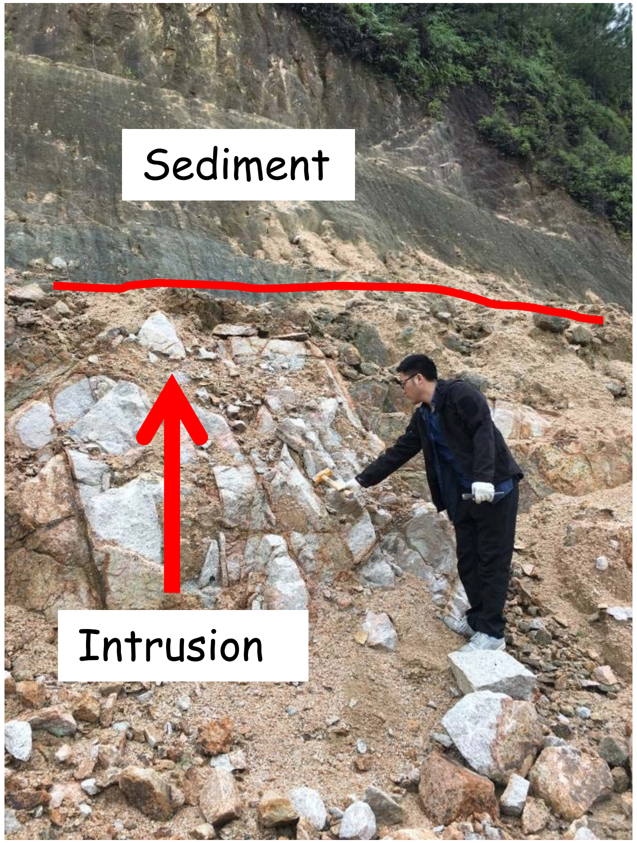
Quartz sandstone (12)

Granite(19)

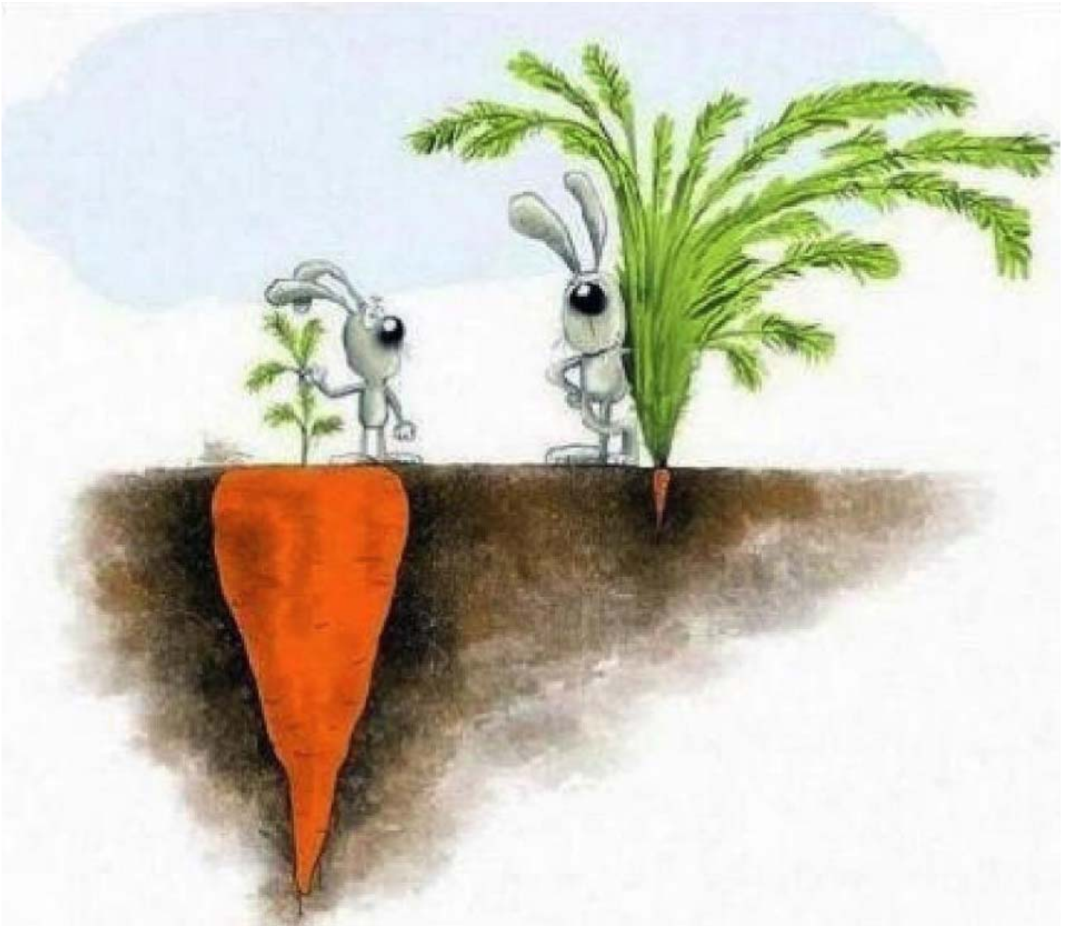
The samples were sent to ministry of nuclear industry.
We are still expecting the abundances of U, Th, and K

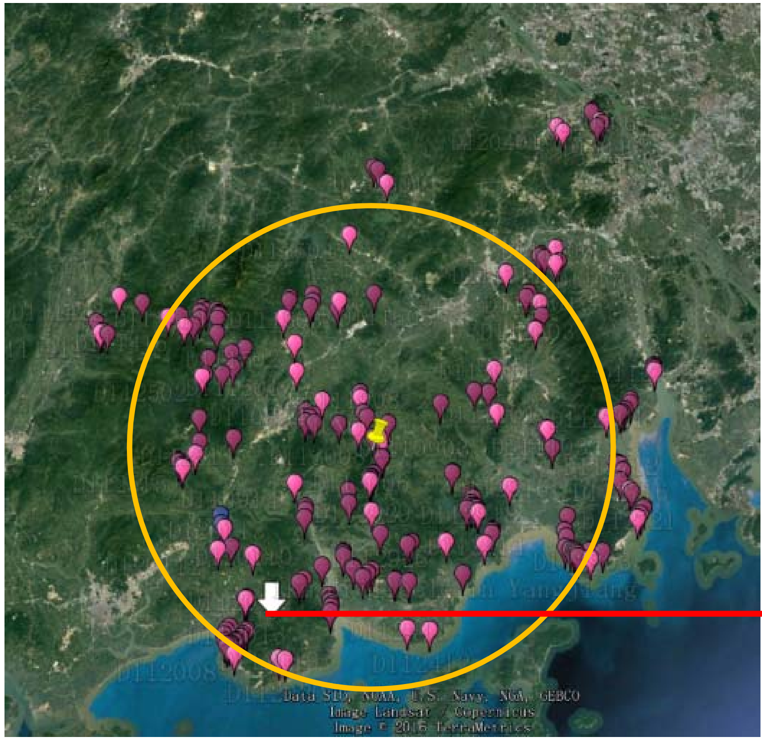
Geological phenomenon



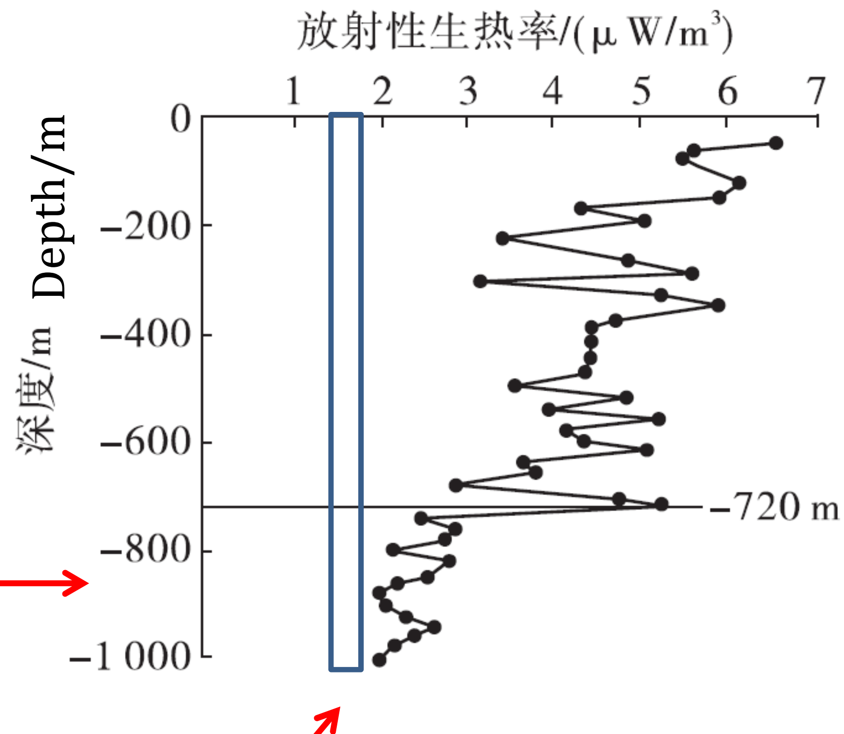


How deep does the surface lithology extend?





Heat production



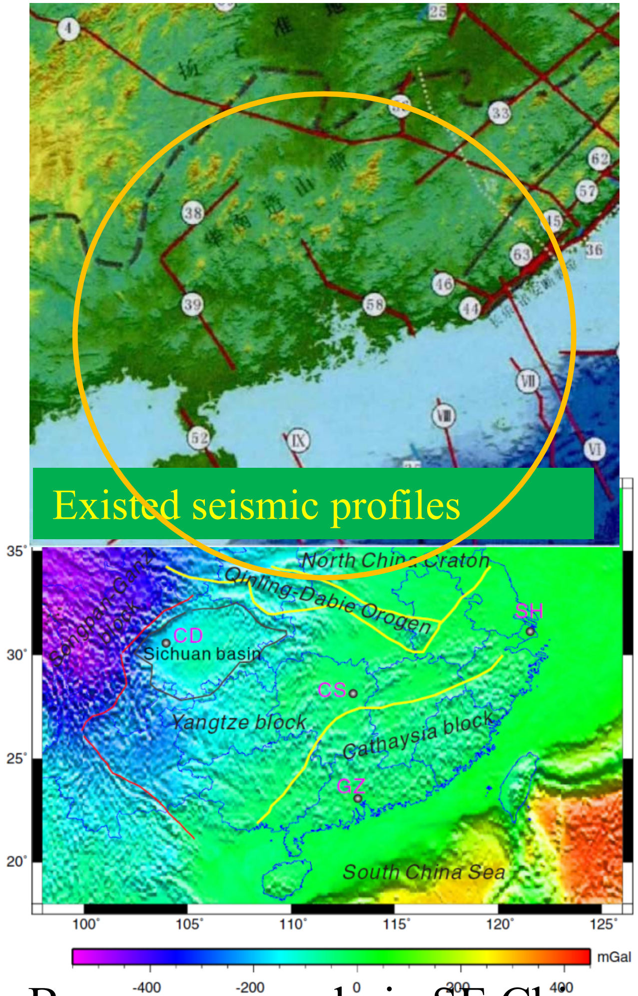
Global averaged UC HP by Rudnick & Gao, 2014

(Zhou et al, 2016)

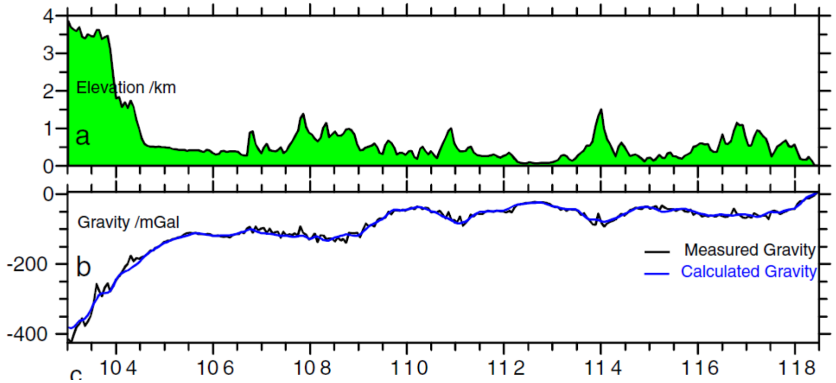
3

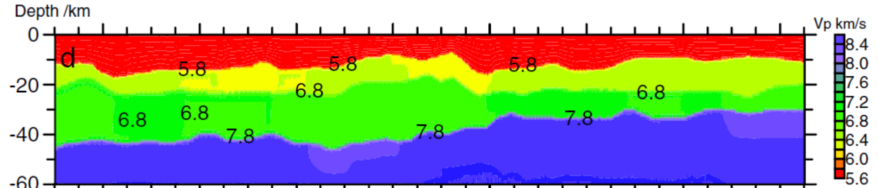
PART THREE

What will we do in future?

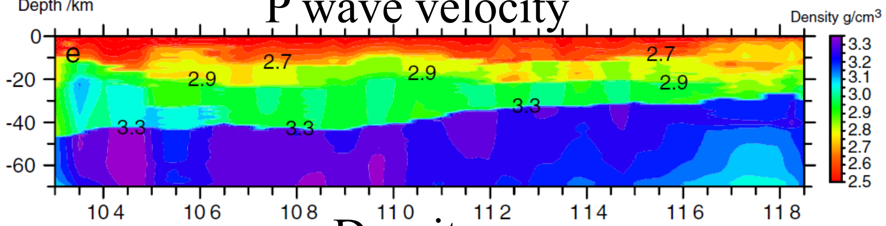


Bouguer anomaly in SE China





P wave velocity



Density

(Deng et al.,2013; Zhang et al.,2013)

- More refined **local crustal structure** (seismology and gravity studies)
- **Composition** (geophysical and geochemical studies)
- Lateral and vertical variation of the **lithosphere**

Conclusion

- We are improving the model with **new data**.
- The significance of this **3D model** extends beyond particle physics, and includes natural resources.
- **Opportunity for geoscientists**. This activity builds a strong geoscientific society to study south China.
- Test this 3D geological model (structure, density, abundance) with **JUNO sensitivity**.

Thank you!