Formation of Yajiang Lithium Ores Revealed by 3D Crustal Imaging

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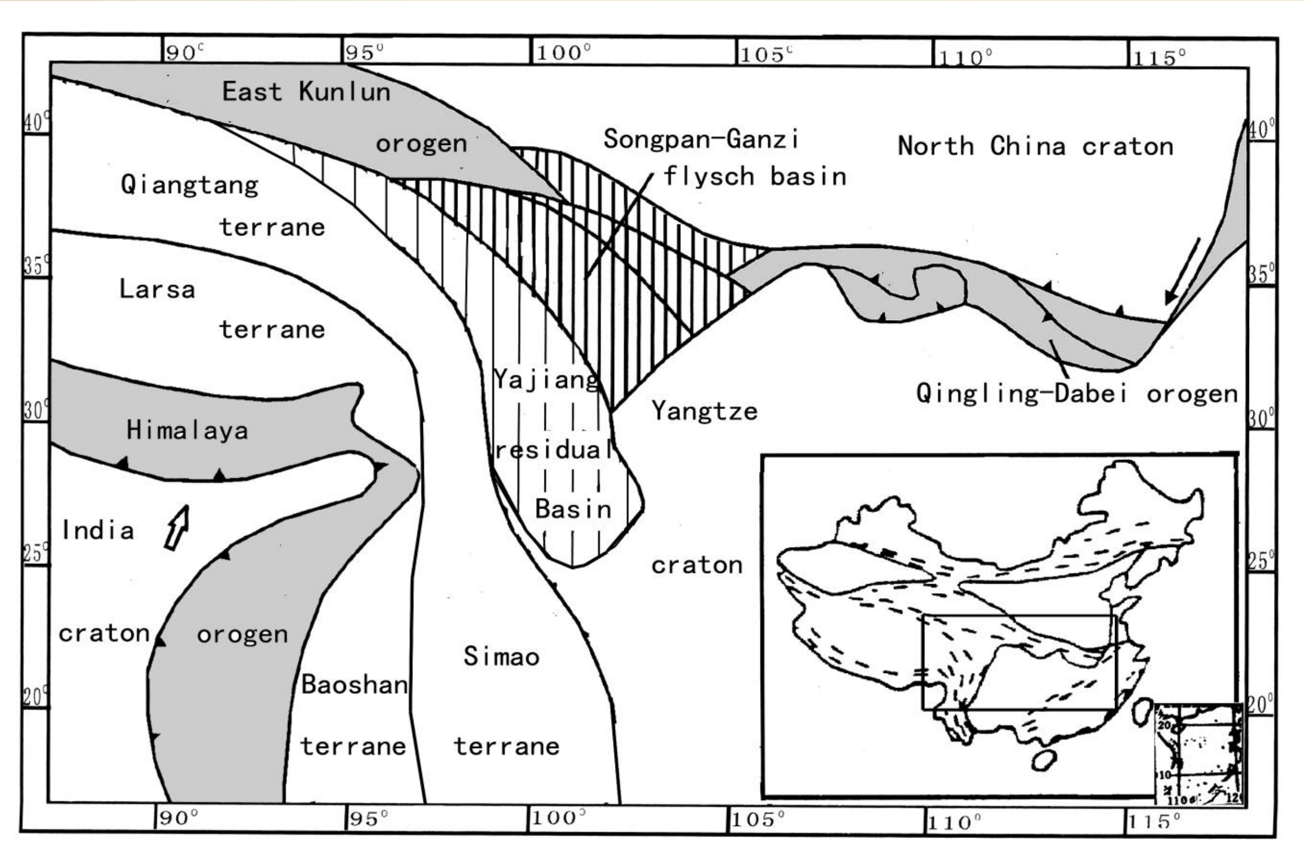
Contents

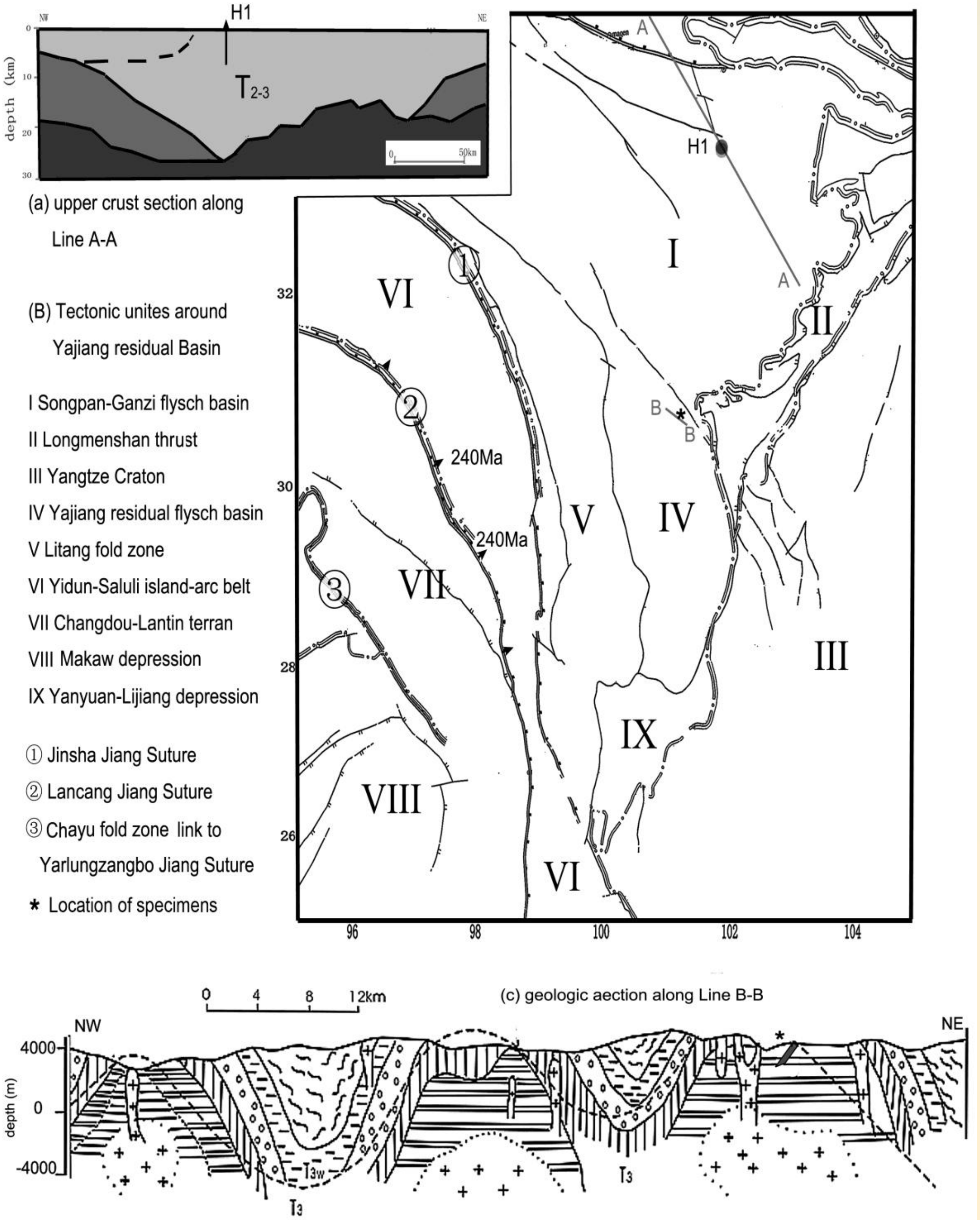
I. Introduction and Scientific Questions

- The lithium deposits is a reliable energy resources for sustainable development of human society.
- How were lithium ore deposits formed?
- Are there enough Lithium deposits available to support sustainable development of the human society?
- This work tries to answer these questions through studies on the crustal structures and evolutional processes of Yajiang residual flysch basin by using new technique of 3D Earth imaging

Yajiang residual flysch basin located in west Sichuan province of China, where the largest spodumene mine in the world was found in the recent years. the grey areas indicate the mountain ranges caused by the continental collisions.



Simplified structural maps of Songpan-Ganzi-Yajiang flysch basin.
(a) Crustal section along line 'A-A' inferred from geophysical investigation and drilling.
(b) Tectonic units and collisional suture lines.
(c) geologic section along line B-B (measured by Xu Zhiqing),
symbol '*' denotes the location of the Jiajika mine and collection spot of specimen



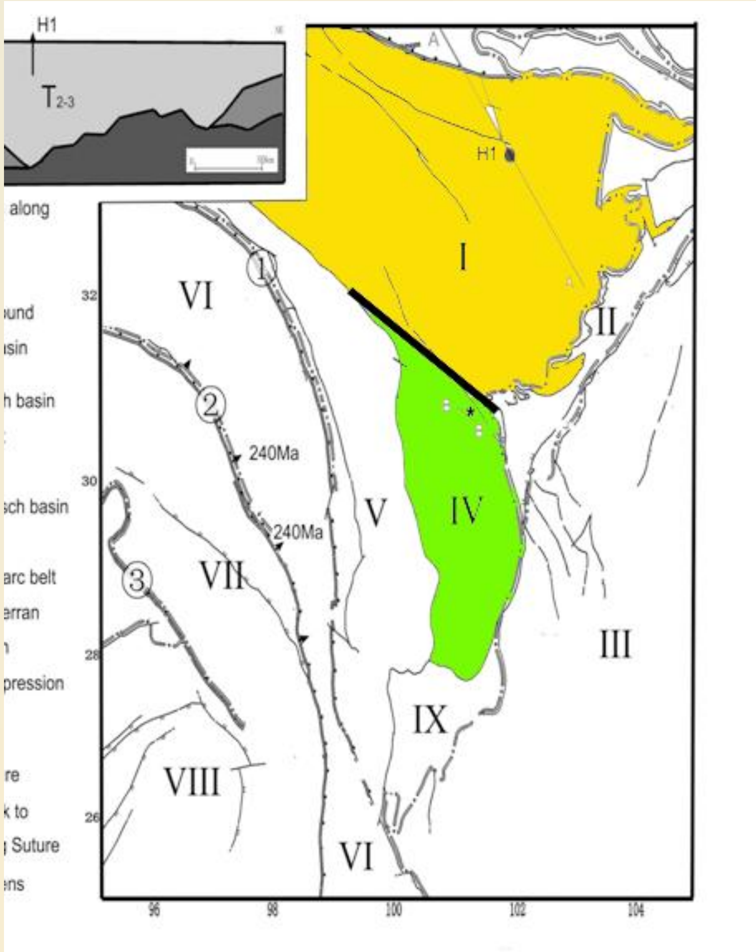
Songpan-Ganzi flysch basin-- Triassic sediments mainly represent the turbidite-facies deposits of continental margin slopes.

the mudstone and limestone similar to the turbidite-facies deposits

located in a continental slope with deep water turbidity flow environment in Triassic.

Yajiang area -- residual flysch basin.

- flysch sediments in Yajiang is not very thick
- Yajiang area contains some domes of crystalline basement rocks, showing expose of the root of the flysch basins.



Specimens within Jiajika spodumene mine

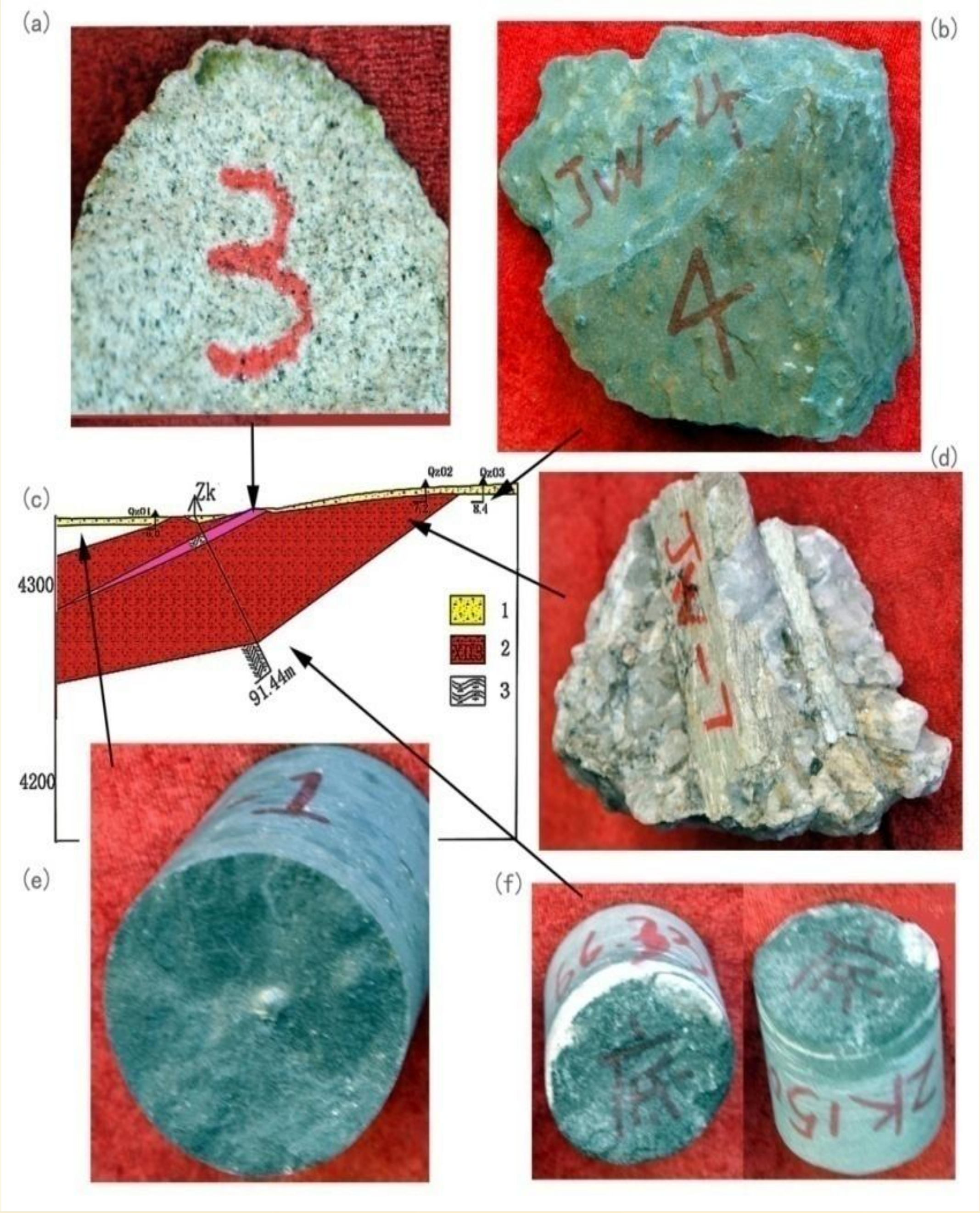
(a) outcrop of granite

(b) T_3 frysch rock

(d) spodumene ore sample;

(e) flysch rock above the ore body

(f) flysch rock beneath the ore body.



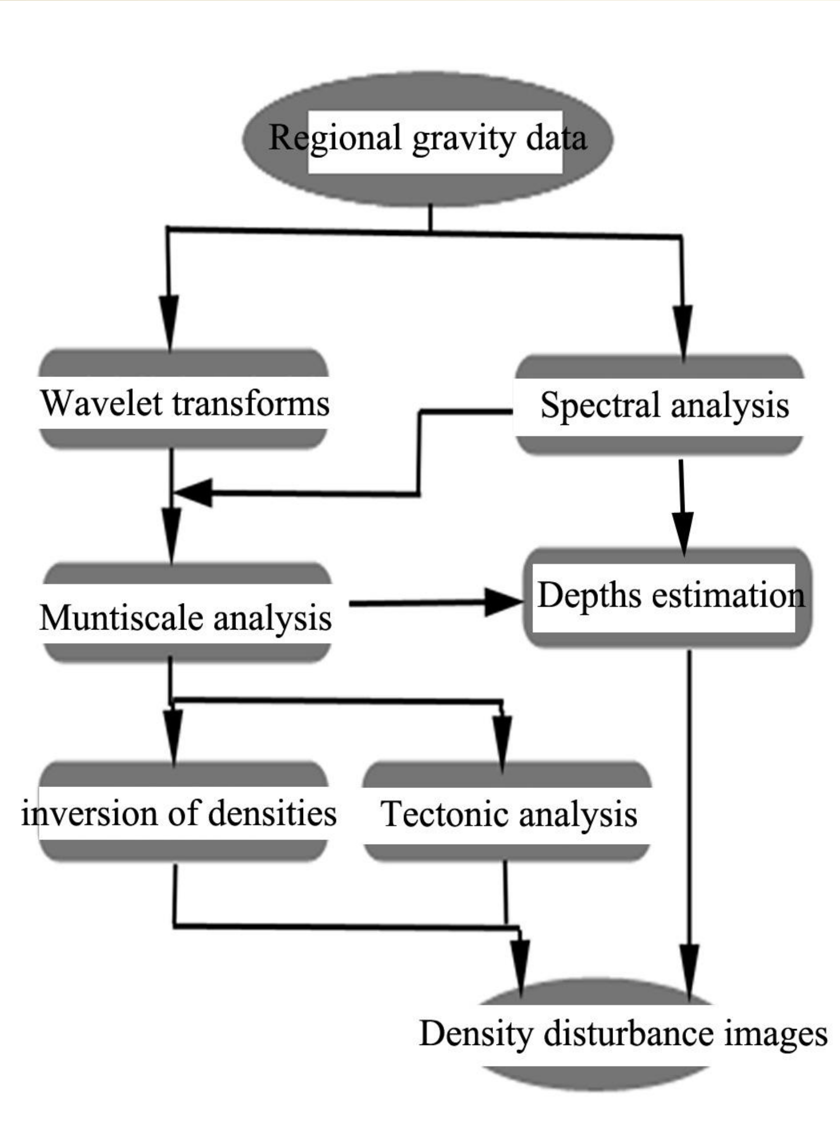
Three quastions

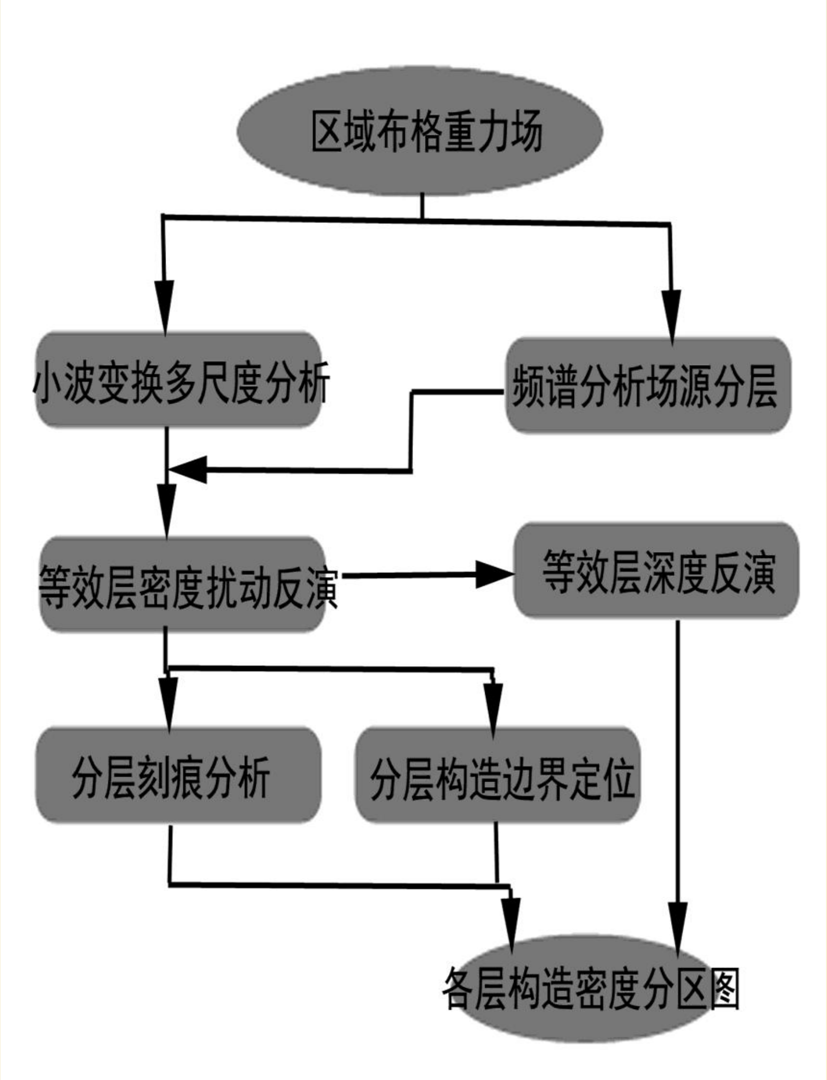
- **Why Lithium come to Yajiang residual flysch basin ?**
- **How Lithium became Spodumene ores?**
- **How these Spodumene ores uplifted close to the surface and exploisible?**
- We have to know:
- **Tectonic Evolution of the Yajiang and origin of Spodumene Mineralization**

II Method for 3D Crustal density Imaging

- For Tectonic Evolution, we must first know the crustal structures.
- By using geophysical investigation data
- To produce crustal images of physical parameters
- The density is the most important parameter for geodynamic reconstruction of tectonic evolution processes

Method of 3D density imaging





multi-scale wavelet analysis of regional gravity field

- a gravity anomaly generated by a single source has its characteristic spatial scale
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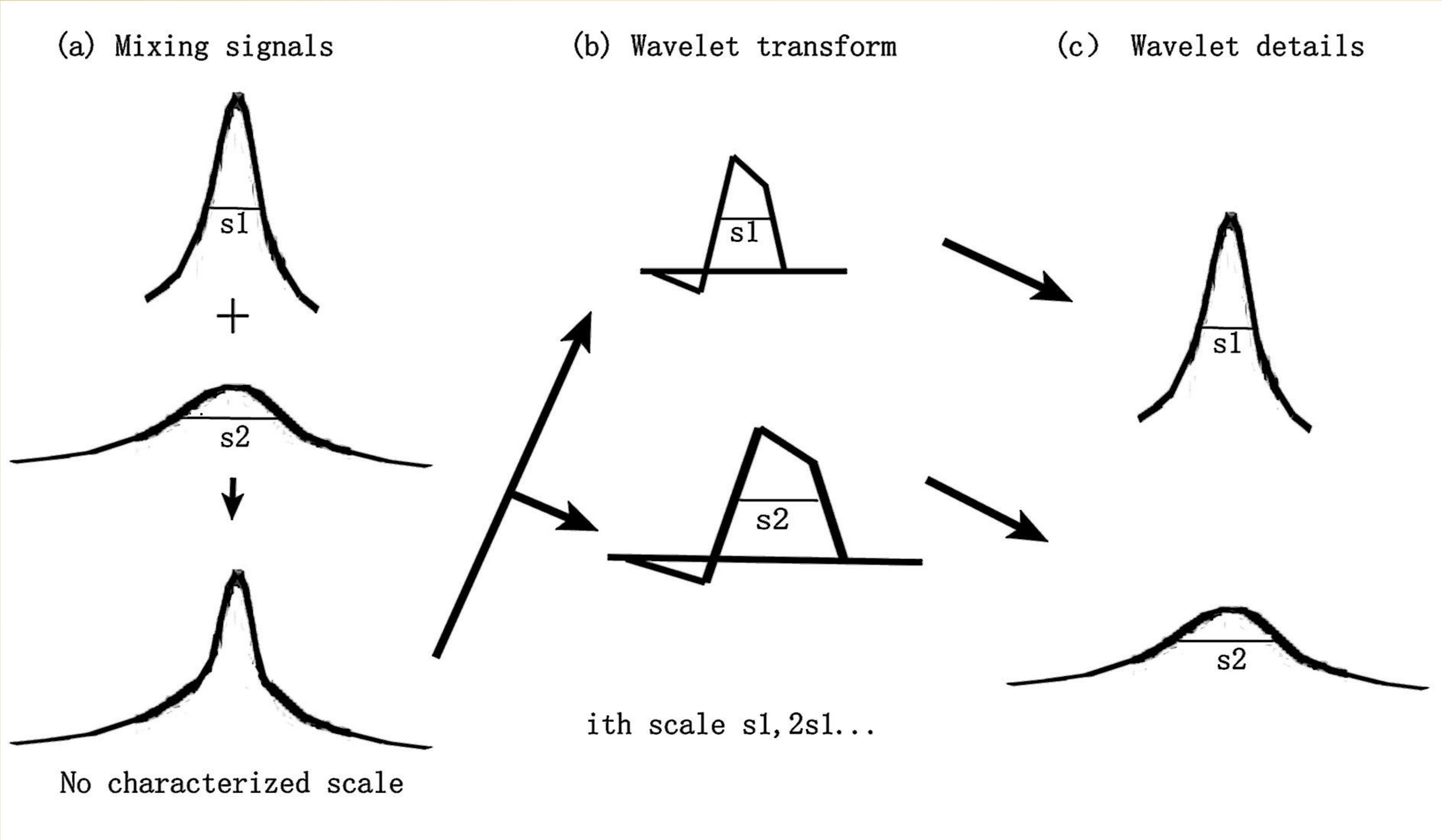
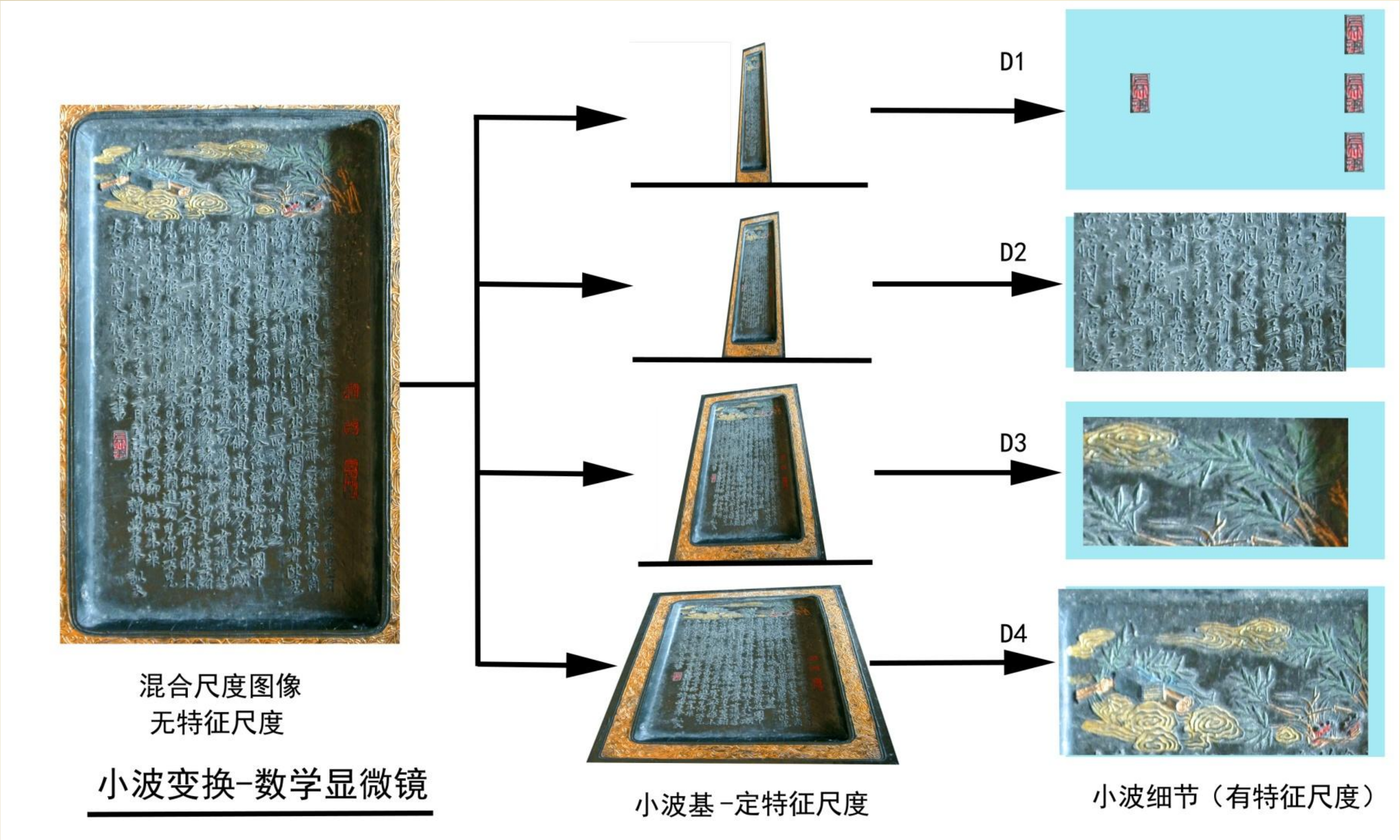
- The characteristic spatial scale is defined by the distance between Half-amplitude points
- The distance is proportional to buried depth of the sources of the gravity anomalies.

Decomposition of gravity field



WT– mathematical microscope



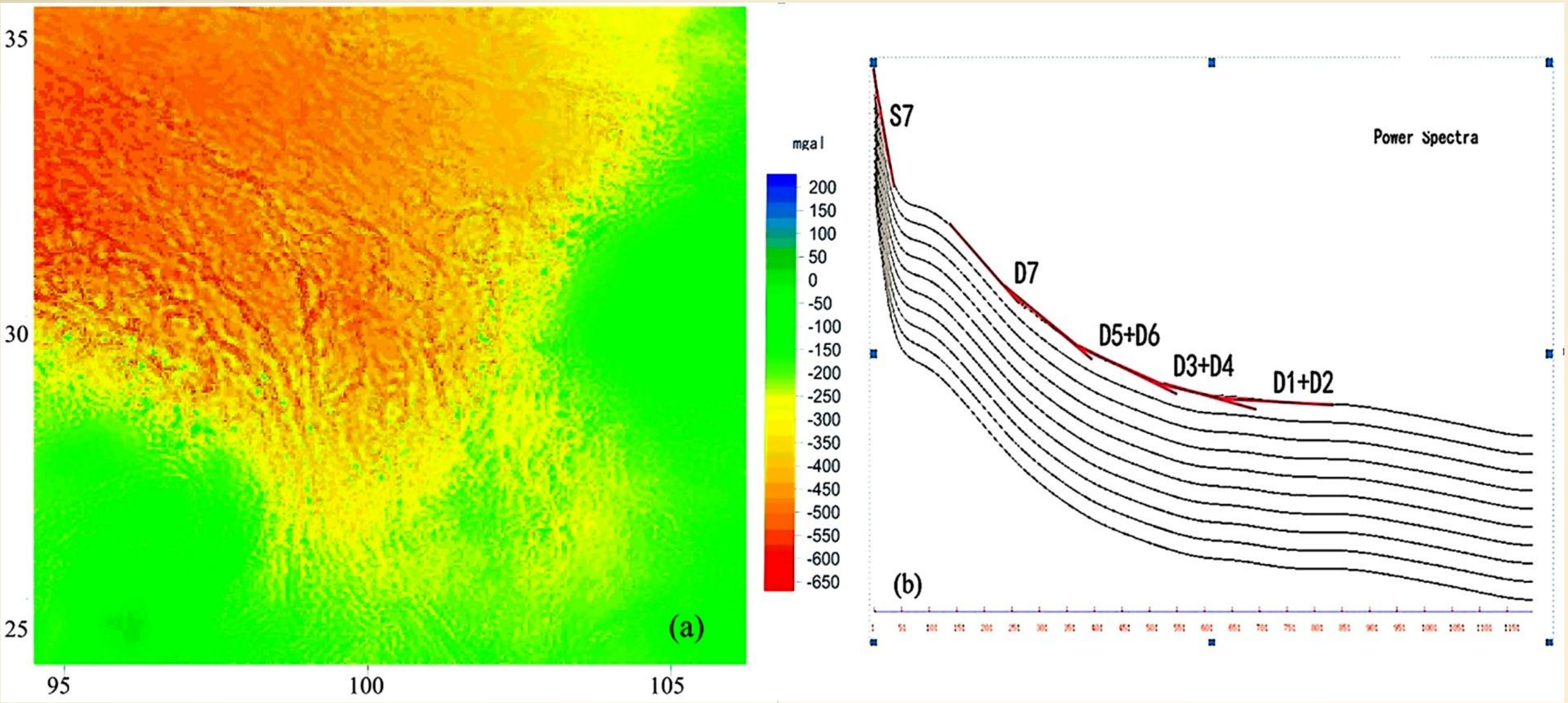
Decomposition of regional gravity field

- we are able to decompose regional gravity field and recover back their characteristic scales.
- The decomposed images corresponding to some equivalent layers with different depths
- Use the method of generalized inversion to delineate 3D crustal density structures .

How to calculate the depths?

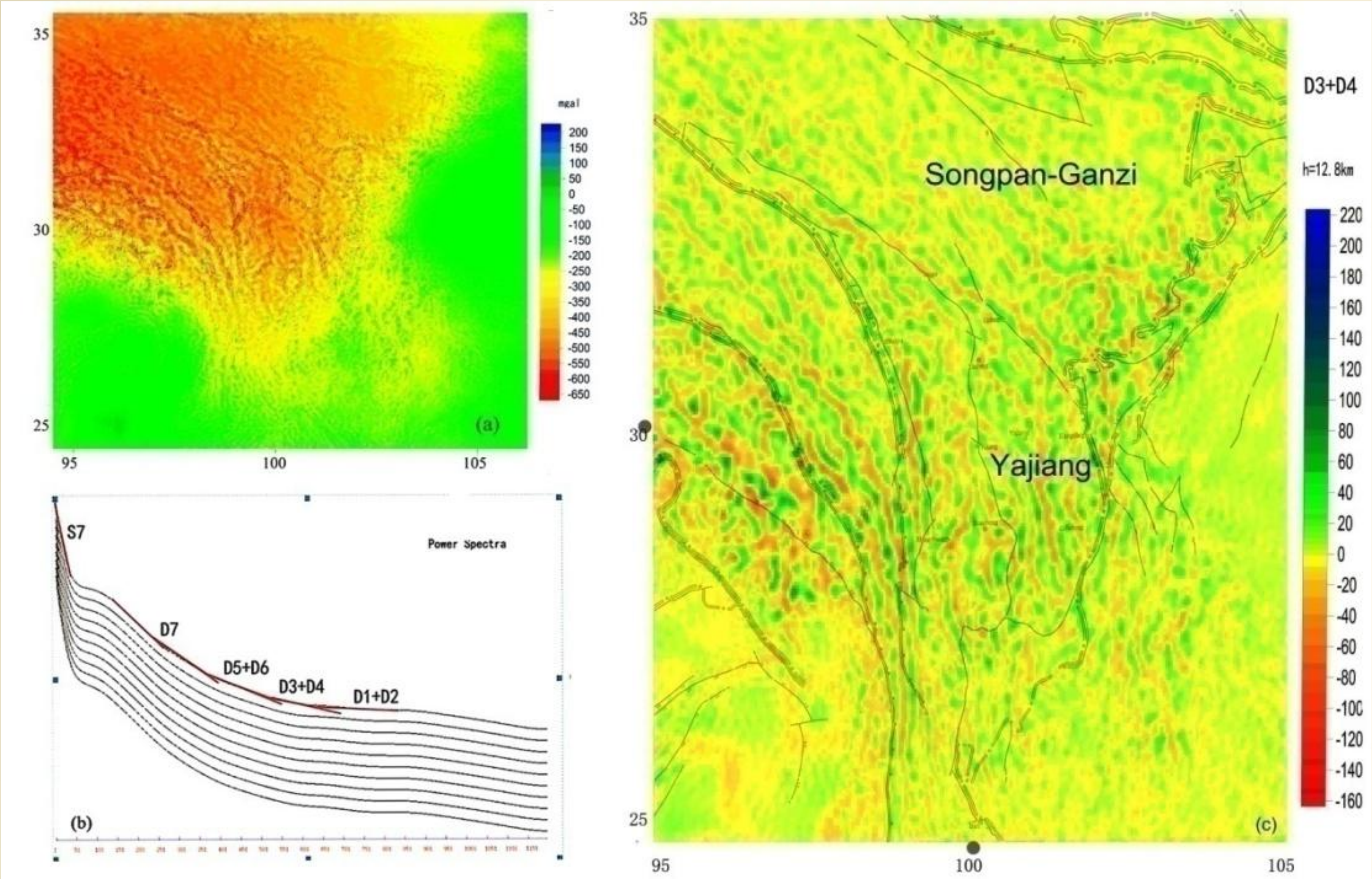
- The slope of the logarithmic power spectrum of the gravity anomaly is inversely proportional to the source's buried depth.
- recognizable straight segments with different dipping slopes in the spectral curves of the superimposed anomalies indicate the buried depths of the different equivalent layers. we know how many equivalent layers can be decomposed from the surface gravity data . The average depth of each equivalent sources' layer can be computed by using the power spectra of the decomposed wavelet details.

the superimposed anomalies of Yajiang area

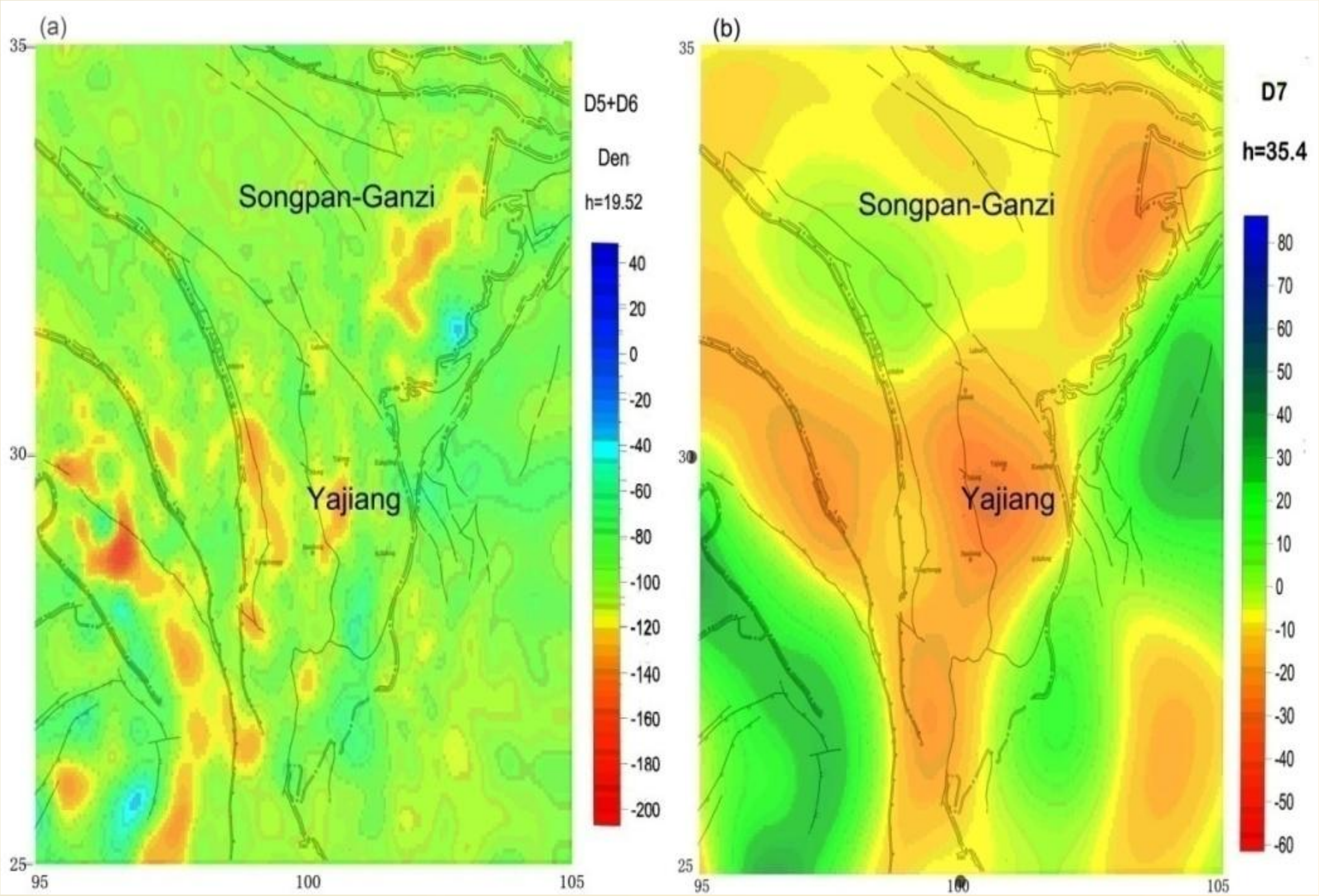


The density perturbation image on plane of depth 12.8 km in the upper crust,

the unit of density perturbations is mg/cm^3



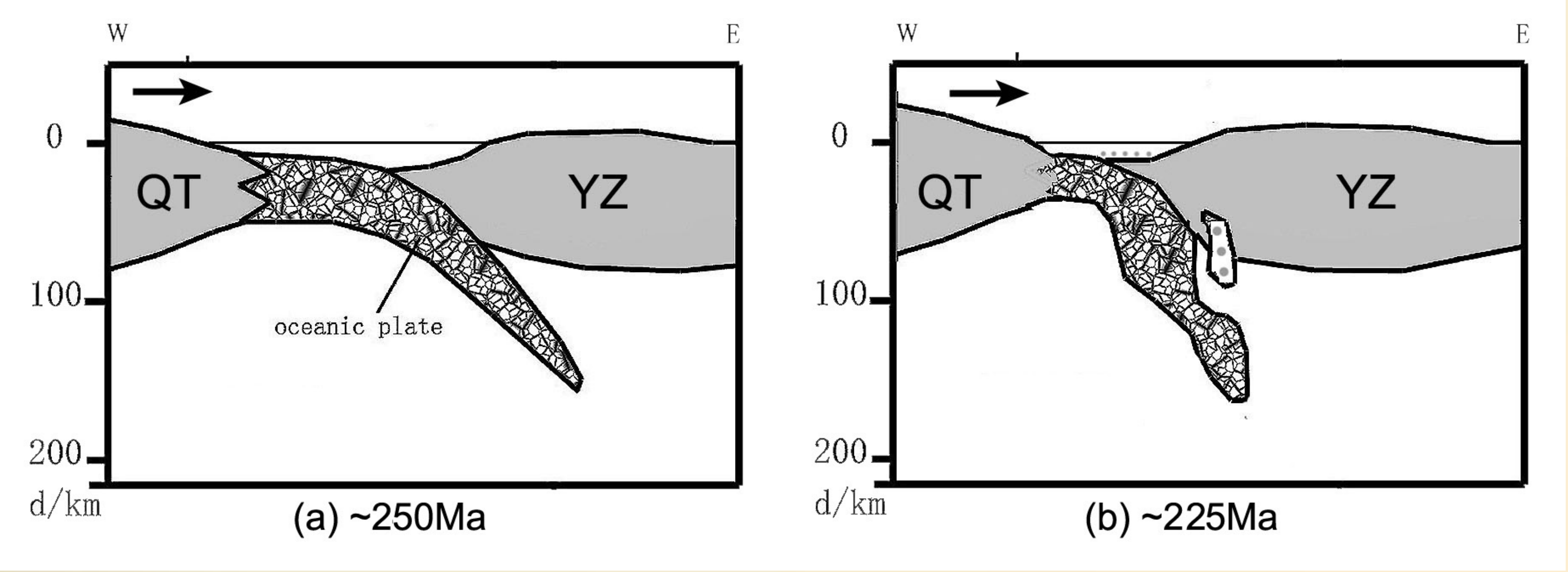
The density perturbation image on plane of depth 19.5 km in the middle crust; （b） the density perturbation image on plane of depth 35.4 km in the lower crust



III. Dynamic process of Yajiang flysch basin and a formation model of Lithium Ores

- tectonic evolution in Yajiang was the same in Songpan-Ganzi and Yajiang flysch basins before Cenozoic
- But Yajiang must be different from Songpan-Ganzi in the Cenozoic as their crustal structures today are different.
- there is an obvious boundary between Songpan-Ganzi and Yajiang in the lower crust

(1) Formation of Songpan-Ganzi and Yajiang flysch basins (240-210Ma). deep sea , the Qiangtang terrane subducted beneath Paleo-Tethys Ocean by its western side



seawater of the Paleo-Tethys ocean was infiltrated downward to the mantle during the subduction

- density of lithium is 0.534 g/cm^3, much lighter than Na (0.97 g/cm^3) and K (0.86 g/cm^3) in the seawater.
- lithium must be relatively hard to infiltrate downward to the mantle through the subduction zone because of the buoyancy.
- lithium in the water of the Paleo-Tethys ocean could accumulated on the seabed deposits of the flysch basin during the subduction, providing original mass supply for later spodumene mineralization.

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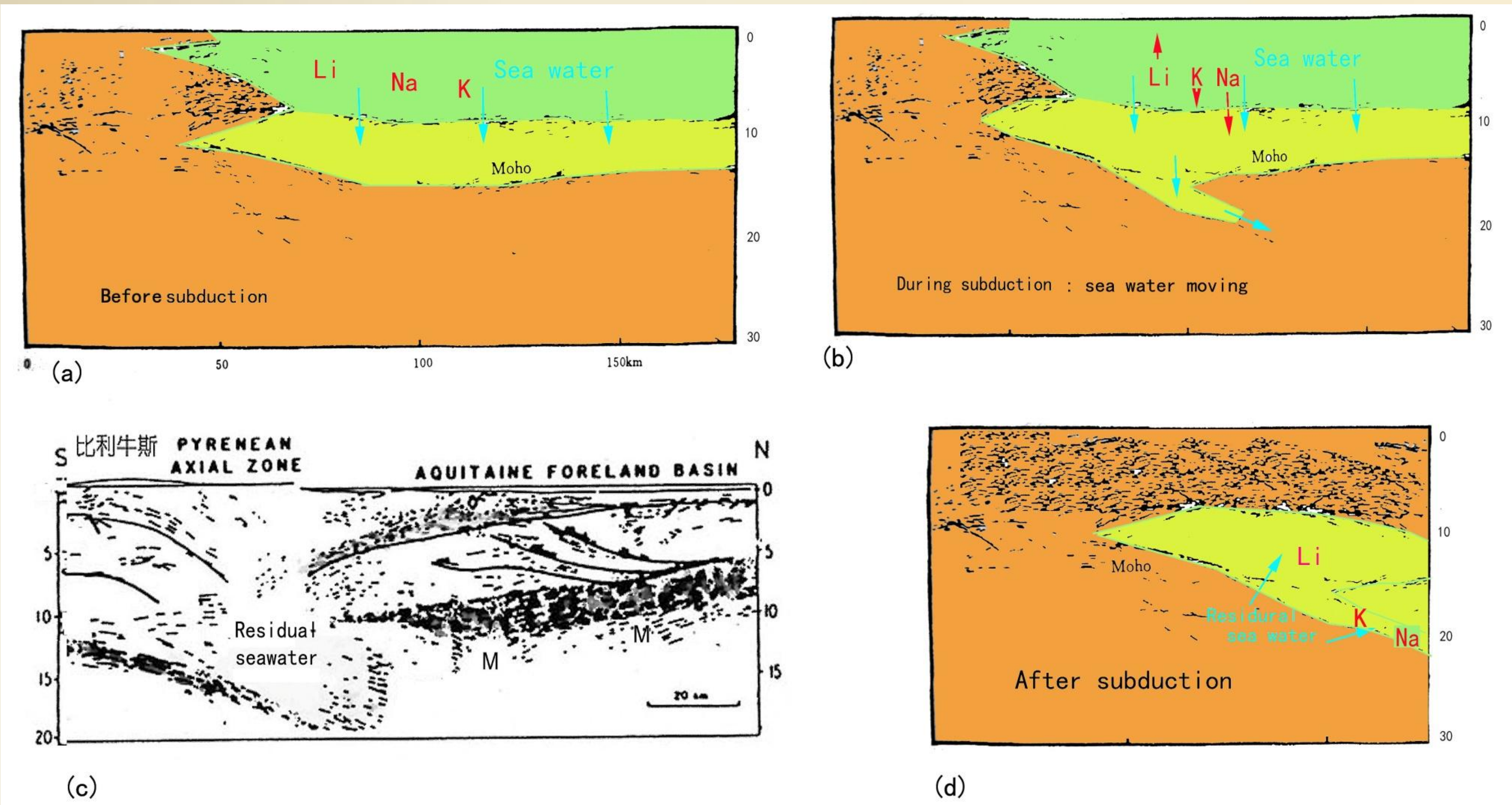
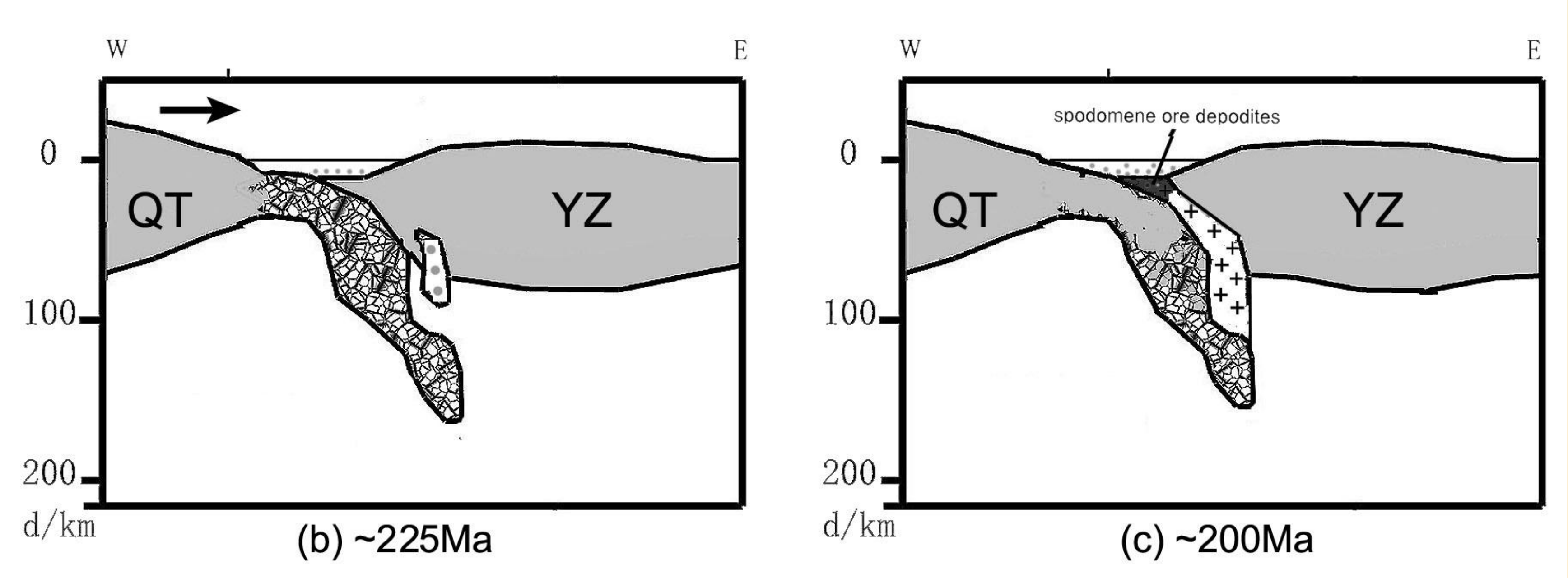
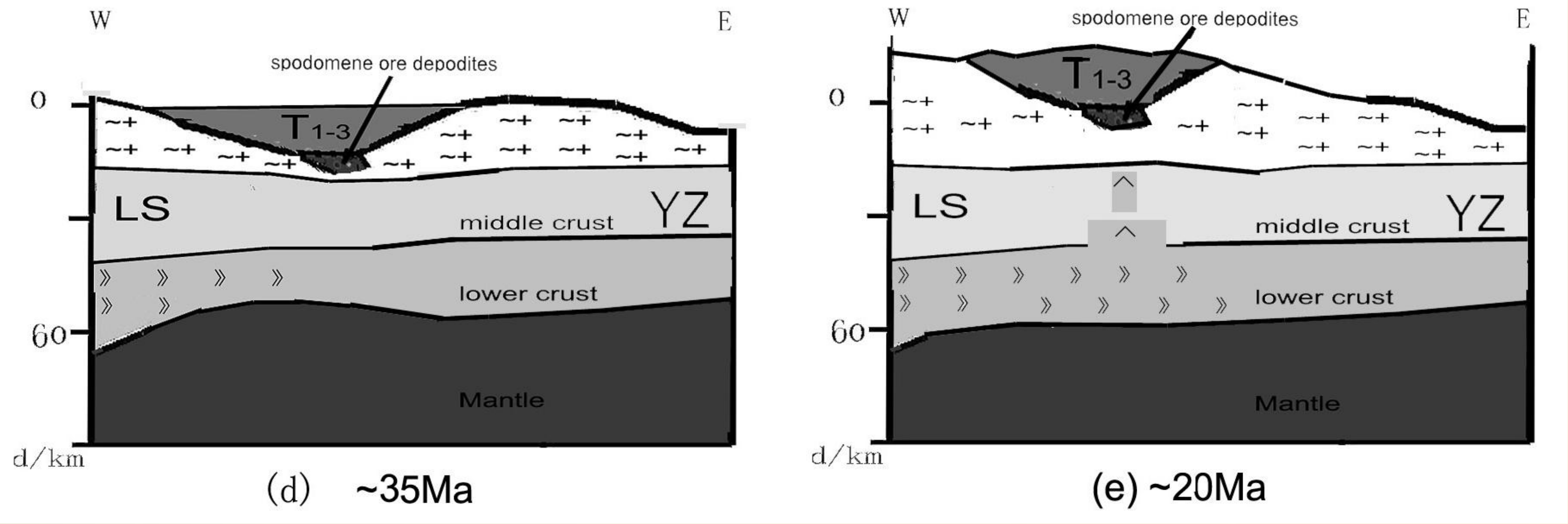


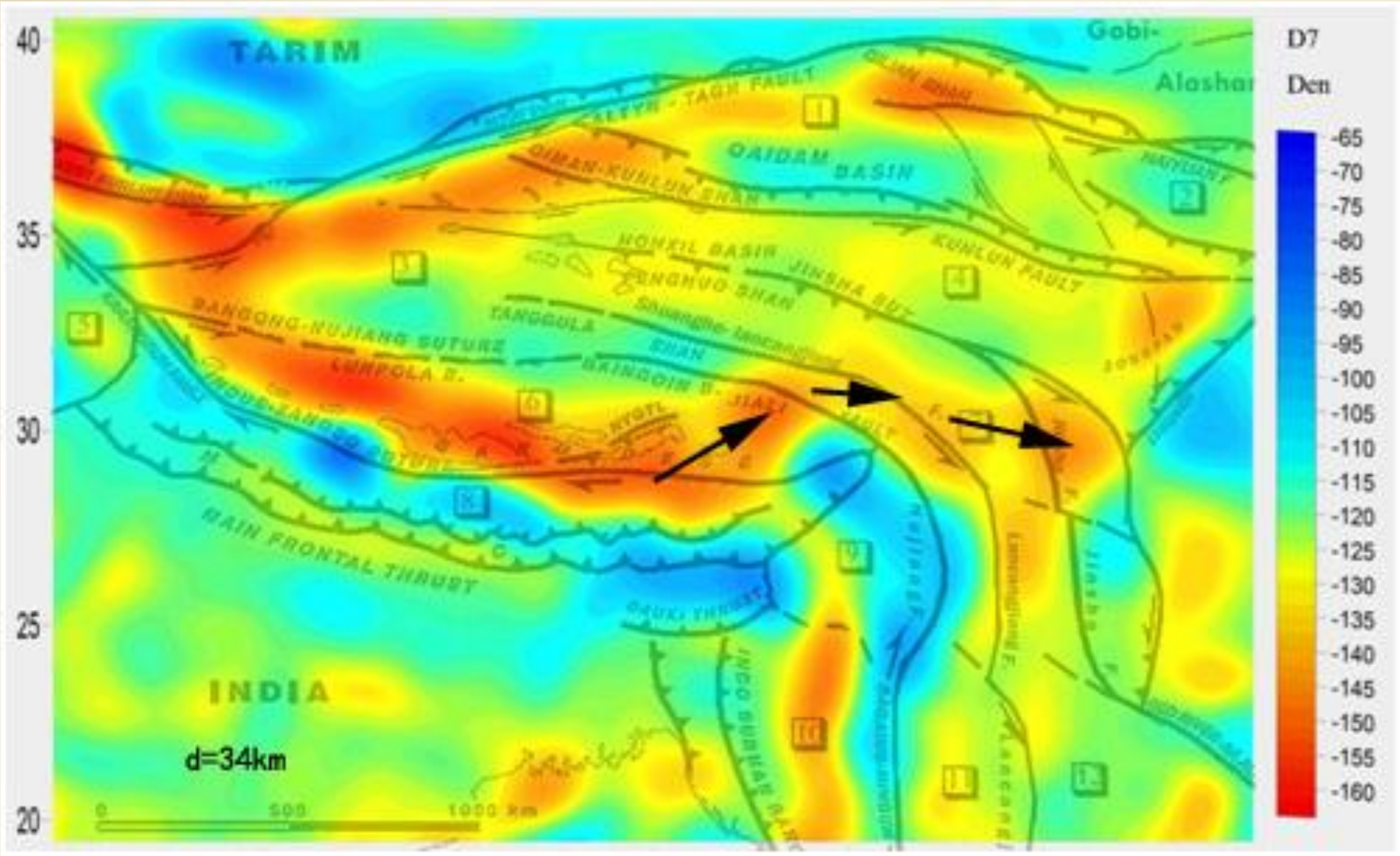
(2) Formation of the spodumene ores in bottom of the flysch basin (215-195Ma). eroded terrestrial masses filled into the basin, forming very thick $T_{2\text{-}3}$ flysch sediments, including some of lithium-rich sedimentary layers on its bottom. infiltrated seawater, causing the lithospheric partial melting and magma domes in the crust, inspiring spodumene mineralization



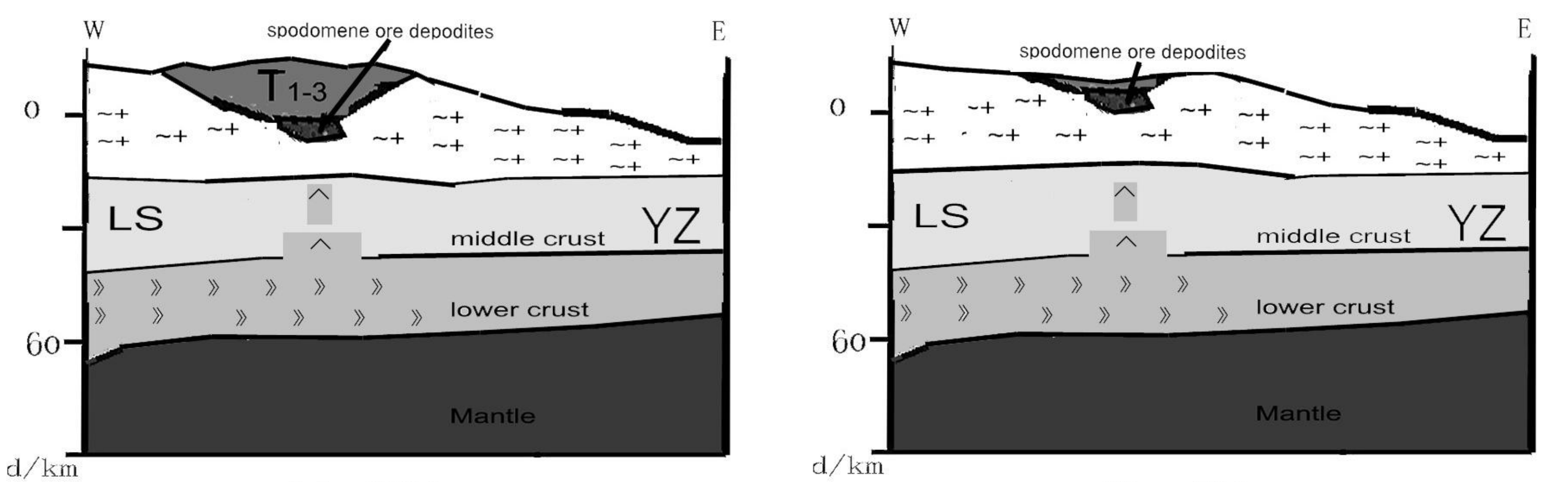
(3) Crustal rock consolidation and metamorphic re-crystallization (190-60Ma)
(4) The lower crustal flows in Tibet Plateau and the Yajiang flysch basin (60-20Ma).



Density perturbation under Qinghai-Tibet Plateau. The lowest-density anomaly is indication the channel flow in the lower crust.



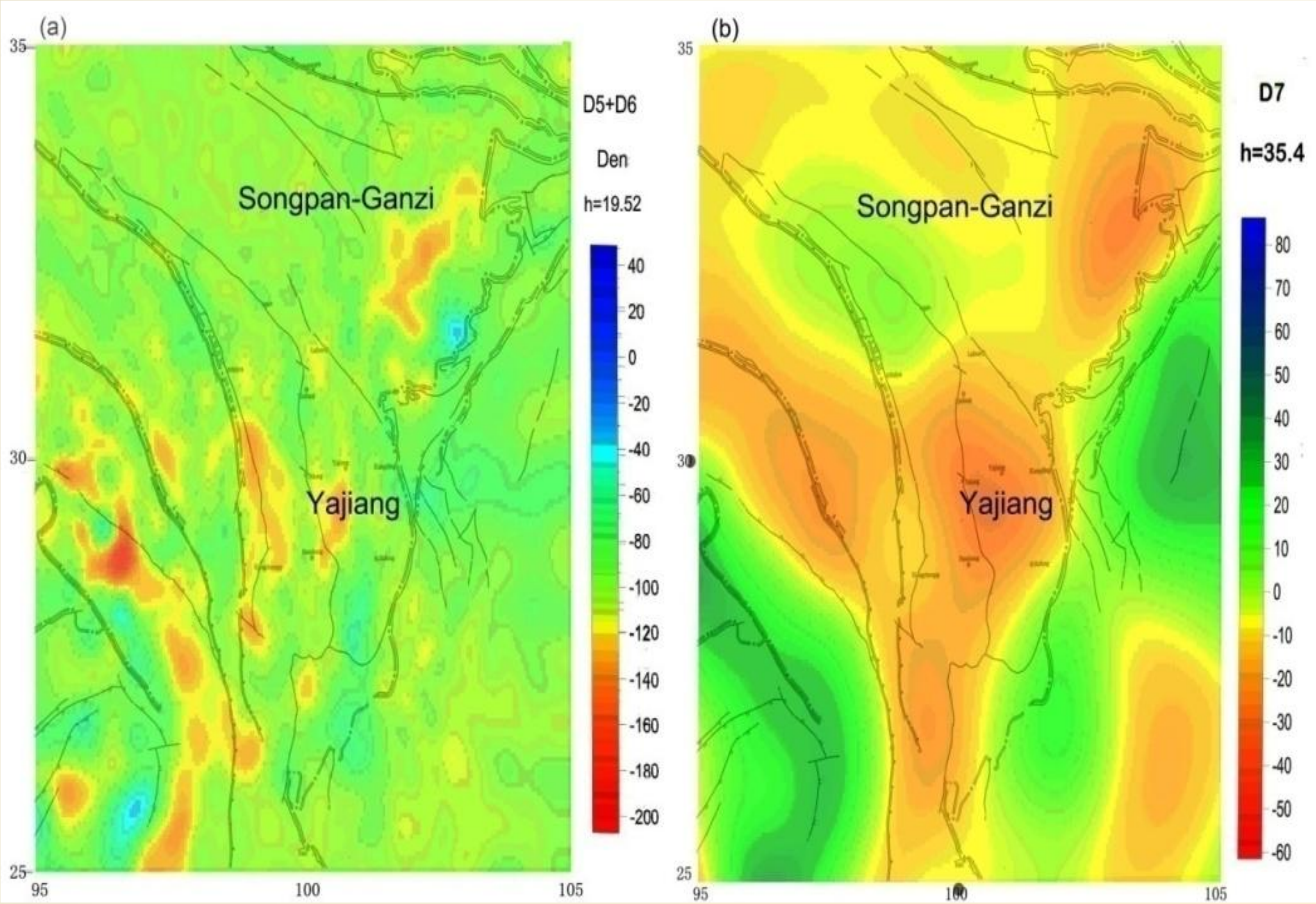
(5) Uplift and erosion of the Yajiang flysch basin (40-15 Ma); (6) Yajiang become a residual flysch basin; the spodumene deposits exposed near the surface,



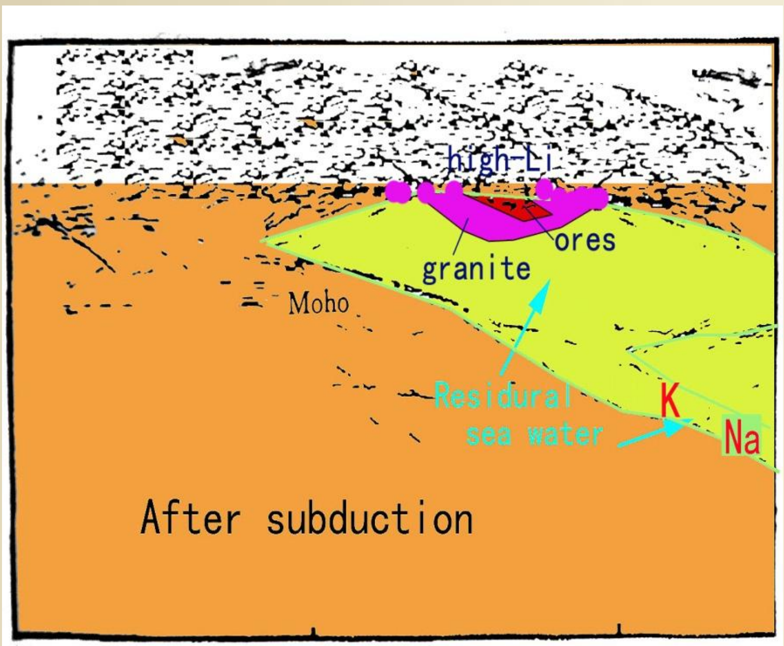
(e) ~20Ma

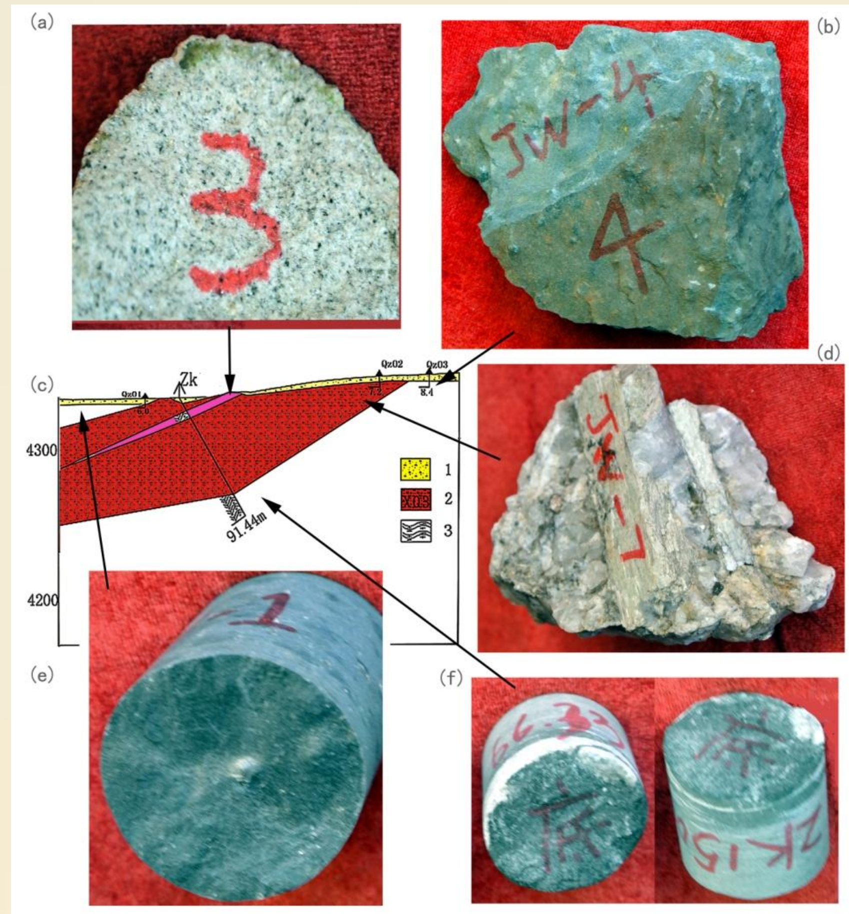
(f) ~ 5Ma

Evidence: Rheological masses extruded upward in the middle crust , made the middle crust thickening and the small-scale low density anomalies



IV. Testing the formation model of Lithium Ores





Testing the Hypothesis

- I predict that the country rocks above the spodumene ores must contain much higher contents of lithium.
- Specimens are sent to National Research Center of Geoanalysis for chemical analysis,
- By plasma spectrograph (Perkinelmer 8300)
- to estimate the contents of related elements.

Testing results

Chemical Analysis Report

Testing set No. QT2016028 Reprot No. GDBQT16028

Specimen No.	JW1-B	JW3-J	JW4-A	JW6-D	JW6-C	JW6-E	JW7-K
Analysis No.	QT16028001	QT16028002	QT16028003	QT16028004	QT16028005	QT16028006	QT16028007
SiO_2 (%)	64.33	73.66	61.33	65.34	66.88	65.36	83.61
Al_2O_3 (%)	17.37	14.65	18.24	16.00	16.39	15.99	10.73
CaO (%)	0.73	0.82	1.11	0.91	1.03	0.78	0.13
TFe_2O_3 (%)	6.60	0.93	6.92	6.89	5.94	7.01	0.55
K_2O (%)	3.34	4.94	3.52	3.35	0.05	3.44	0.84
MgO (%)	2.28	0.18	2.53	2.64	2.23	2.68	0.05
MnO (%)	0.09	0.03	0.11	0.09	0.17	0.07	0.20
Na_2O (%)	1.04	3.23	1.56	1.24	1.72	1.15	2.21
P_2O_5 (%)	0.13	0.17	0.14	0.15	0.06	0.16	0.06
TiO_2 (%)	0.74	0.07	0.80	0.68	0.58	0.67	0.01
LOI (%)	3.13	0.79	3.61	2.23	1.34	2.26	0.68
Li (μg/g)	above 1112	granite 319	above 846	242	75.4	beneath 153	ore 5154
Rb (μg/g)	150	306	186	173	2.79	175	270
Cs (μg/g)	131	51.0	138	20.0	1.50	19.9	52.2
Be (μg/g)	2.38	8.65	2.44	4.24	17.6	0.76	4.42
Sr (μg/g)	75.5	38.7	107	82.5	67.3	77.6	4.68
Ba (μg/g)	342	70.8	400	329	11.5	330	8.98
Ga (μg/g)	25.3	20.2	25.1	22.3	19.8	20.9	26.3
As (μg/g)	0.40	0.89	9.38	0.36	0.77	0.23	0.98

Conclusion

- When oceanic seawater infiltrated downward through a subduction zone, the lithium-rich saltwater accumulating on the sea bottom under the effect of buoyancy.
- Later on bed of Yajiang flysch basin, magmatic hydrothermal process causes lithium mineralization, creating original spodumene ore bodies.
- Only after crustal thickening, weathering and erosion, the spodumene deposits could be uplifted near the surface and become exploitable energy resources.
- This hypothesis is tested by chemical analysis of the country rocks and ore specimens, obtaining positive evidences.
- Since there are widely distributed similar flysch basins in the world and some of them have been uplifted, prospecting potential of spodumene deposits similar to Yajiang’s seems optimistic.

Thank You

- **Reconstruction of geodynamic processes is the key for understanding our Earth**