Development and driving mechanisms of groundwater flow systems in hyper-arid endorheic basins

——*a case from Tibetan Plateau*

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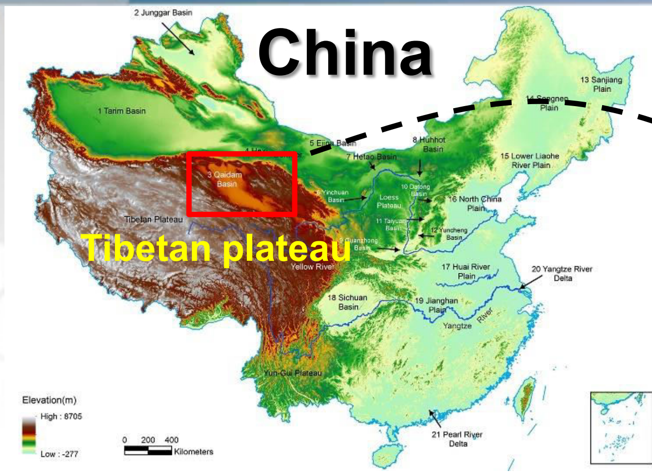
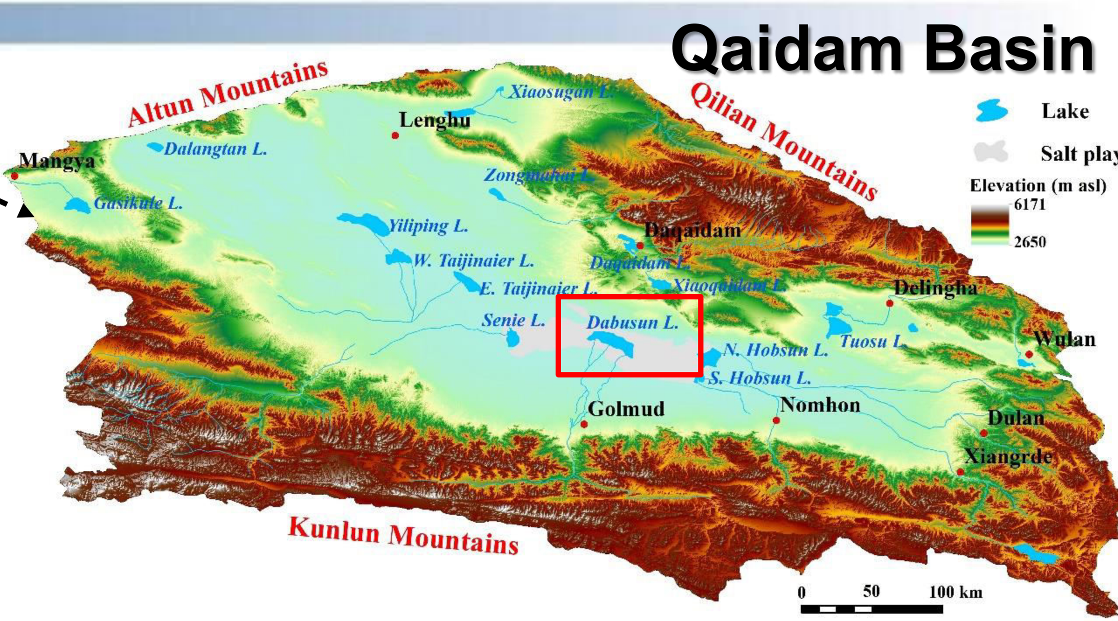
Sep. 11-15, 2023, Beijing

Outline of Presentation

1. Research Motivation and Study Area
2. Methodology
3. Results and Discussion
4. Conclusions

1、 Research Motivation and Study Area

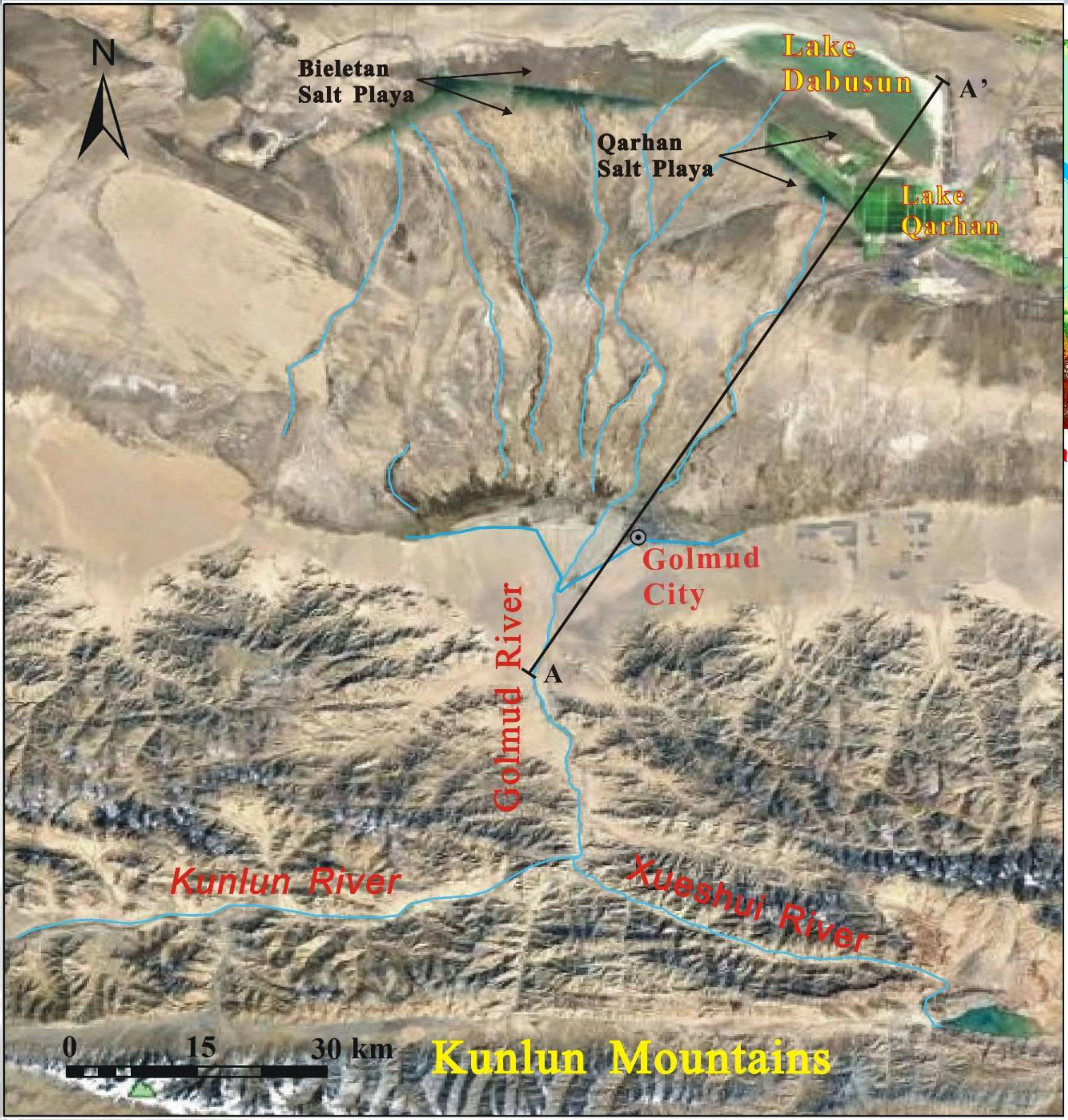




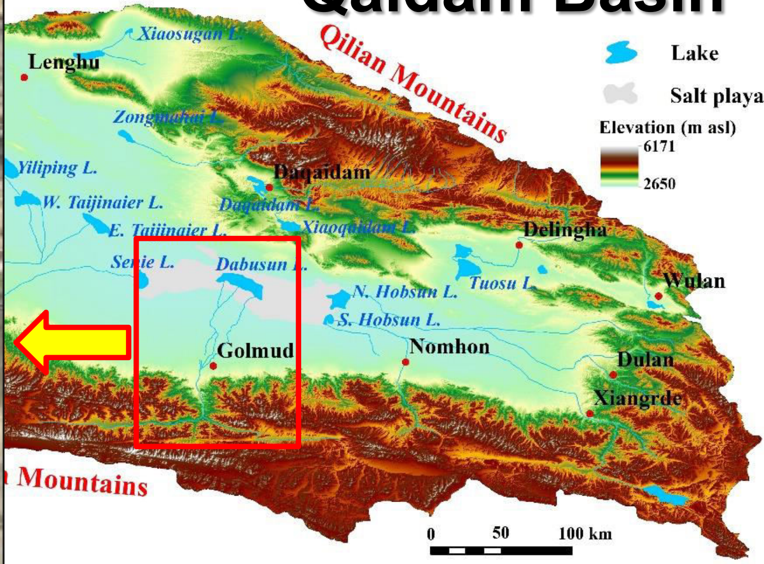
Global warming + precious resource + fragile eco-environment

Deeply understanding water behaviors is significantly important.

1、 Research Motivation and Study Area



Qaidam Basin



Golmud River Watershed

Precipitation ＜50 mm

Evaporation＞2600 mm

2、Methodology

Zone 1: Mountainous area;
Zone 2: Alluvial fan plain;
Zone 3: Overflow zone;
Zone 4: Transition zone;
Zone 5: Terminal lake zone.

1. Modelling (TOUGH2)
2. Major ions
3. Isotopes
   (δ^2H, $\delta^{18}O$, ^3H, ^{14}C)

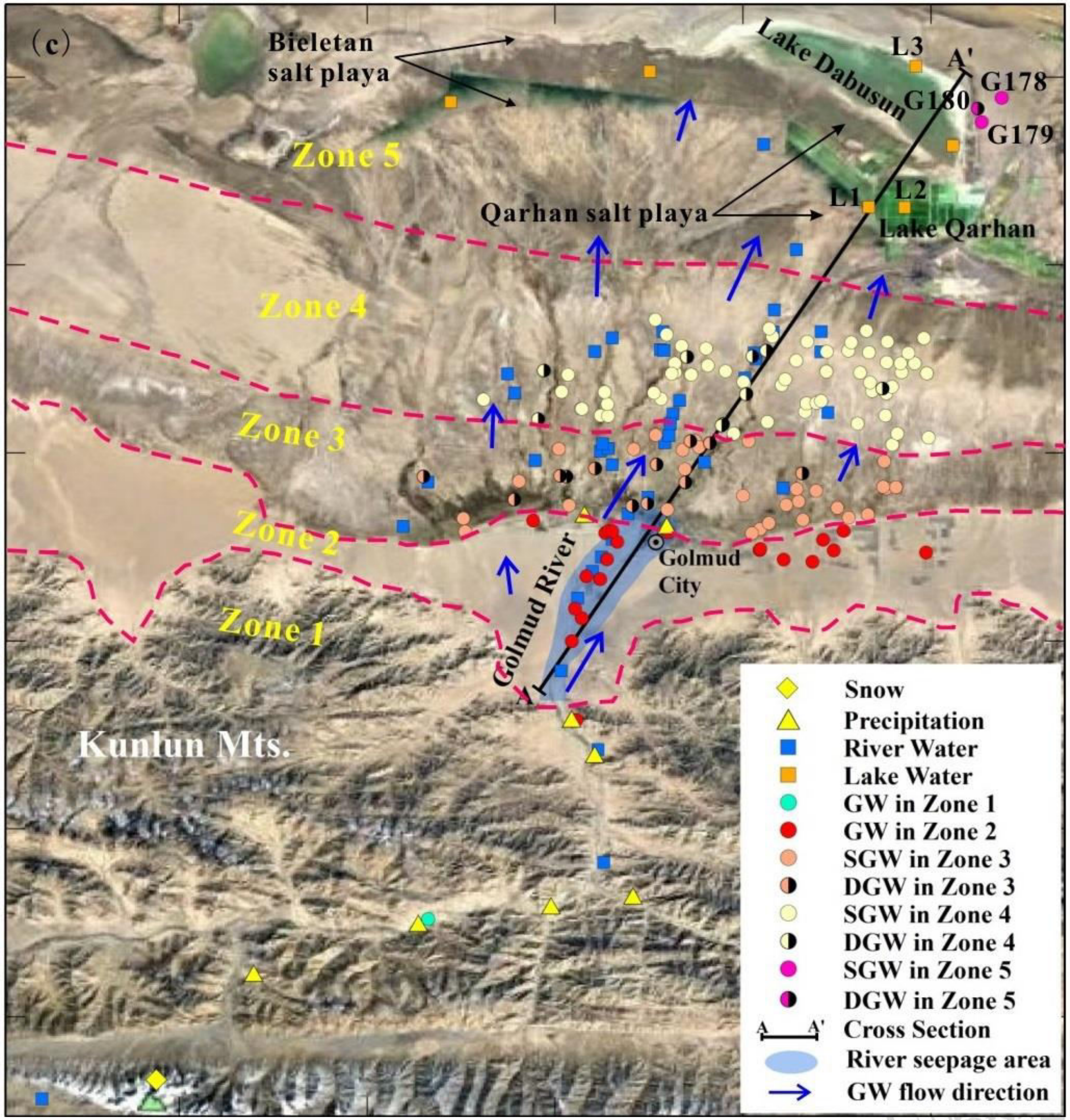
AVAILABLE DATA:

(1) *180 Groundwater (GW) samples*

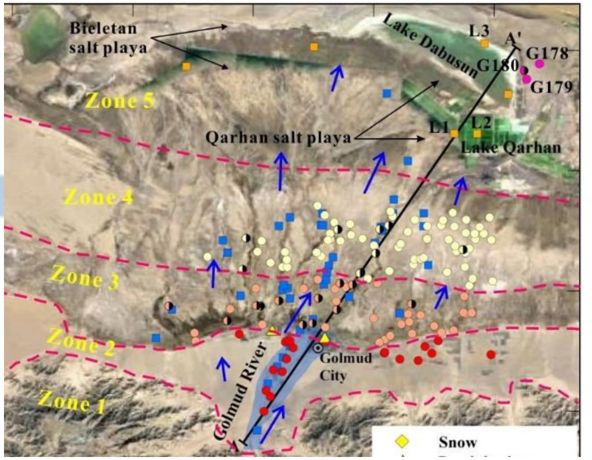
(2) *48 Surface water (SW) samples.*

(3) *90 Brines water samples*

(4) *8 Precipitation samples*



3、Results and Discussion



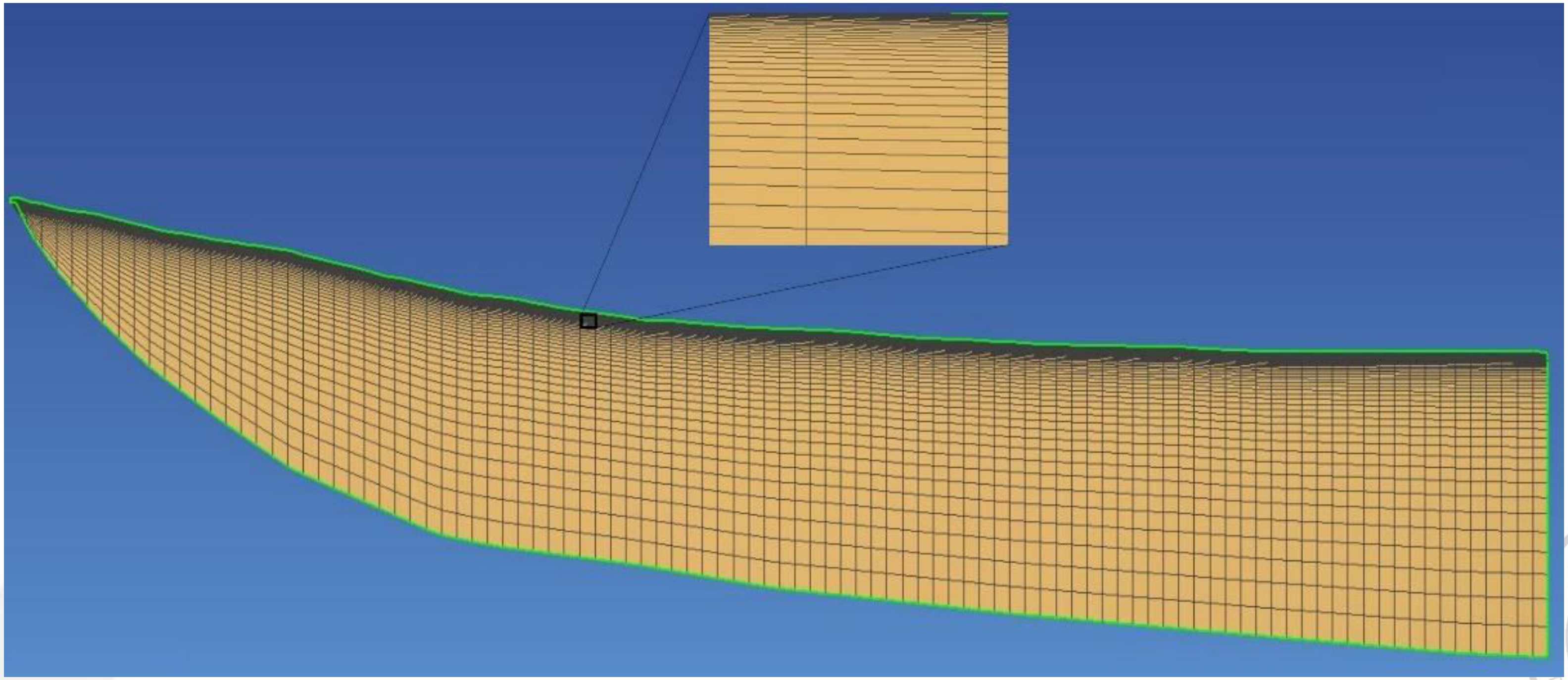
Groundwater simulation

——*TOUGH2 software*

Length：100 km → 100 cells with equal size (Horizontal direction)

Depth：1300 m → Variable meshing with the min size of 0.1m near surface；

Width：1 m → 1 cell.



3、Results and Discussion

Groundwater simulation

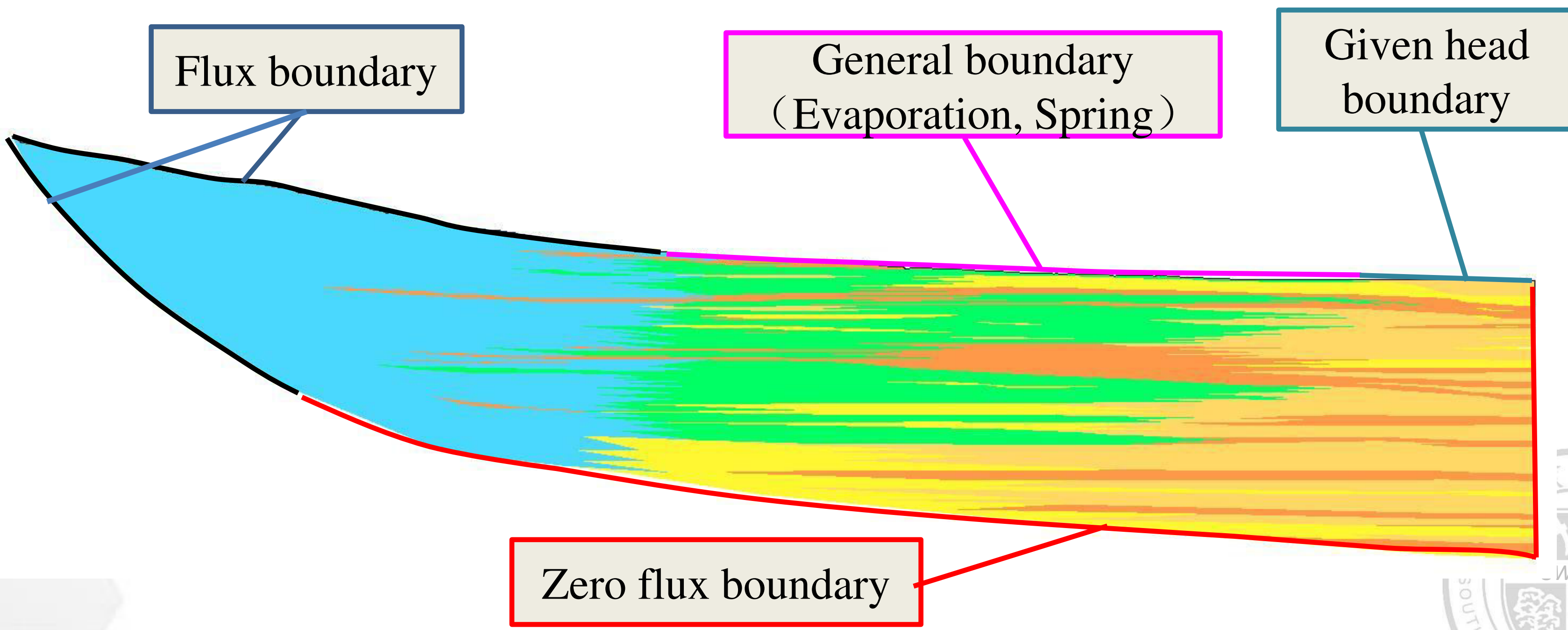
Initial Parameters： $K_h=10^2 \sim 10^{-3}$ m/d，K_h/K_v=5~10；

Recharge rate and initial head： Average of Multi-year;

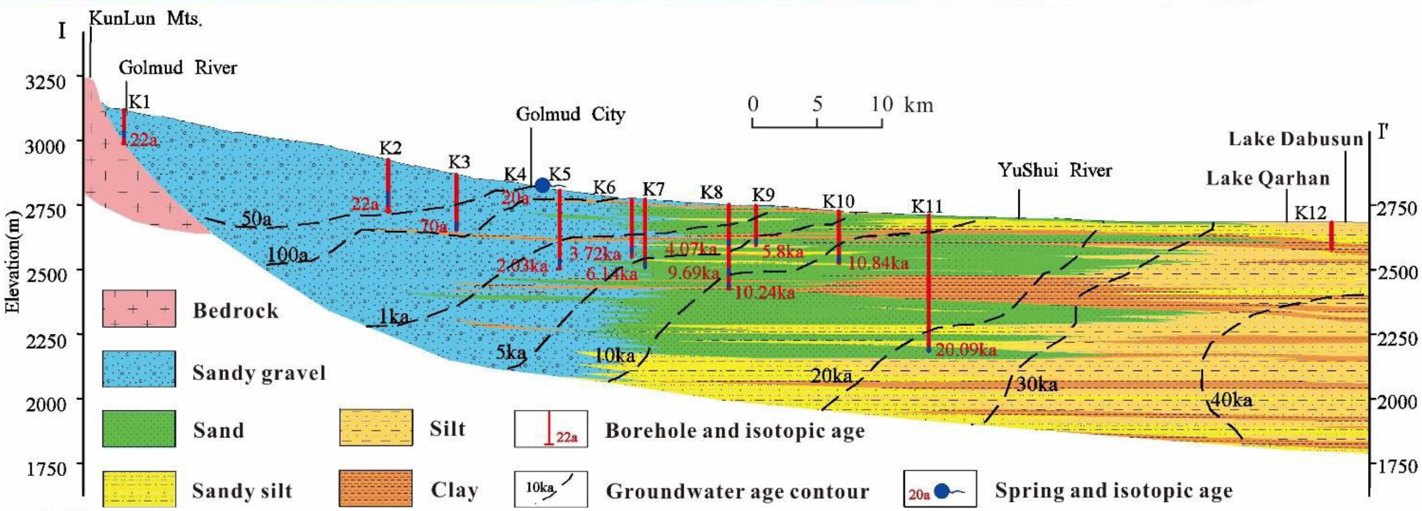
Evaporation： Using the Evaporation module developed by *Hao et al. (2016)*,

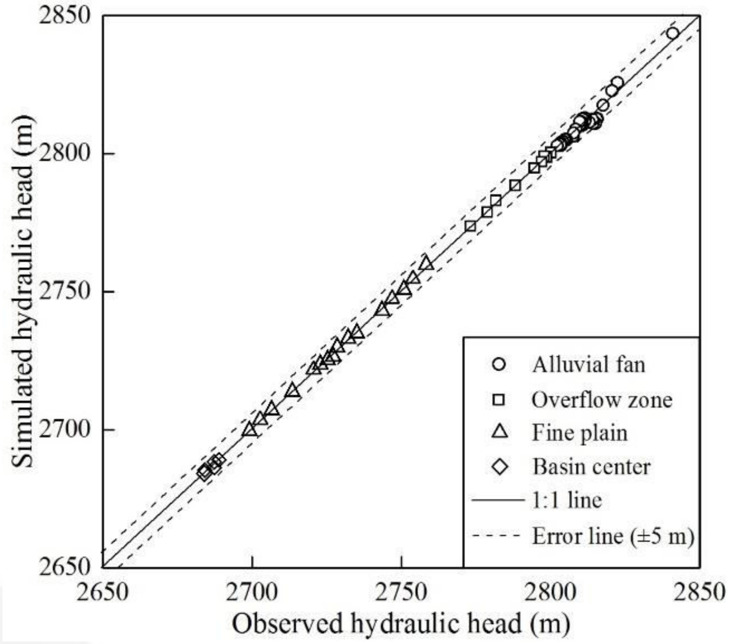
Potential evaporation rate is 2600 mm.

Spring： Using the DELV module in TOUGH2。



3、Results and Discussion





observed heads vs. simulated heads

Calibration results show that the model can be used to reveal the groundwater flow pattern.

3、Results and Discussion

Estimated parameters of different lithology

Lithology	K_h (m/d)	Anisotropy ratio K_h/K_v	Porosity
Gravel sand	56.3	10	0.35
Sand	13.7	10	0.40
Sandy silt	0.62	5	0.5
Silt	0.13	5	0.6
Clay	0.001	5	0.65

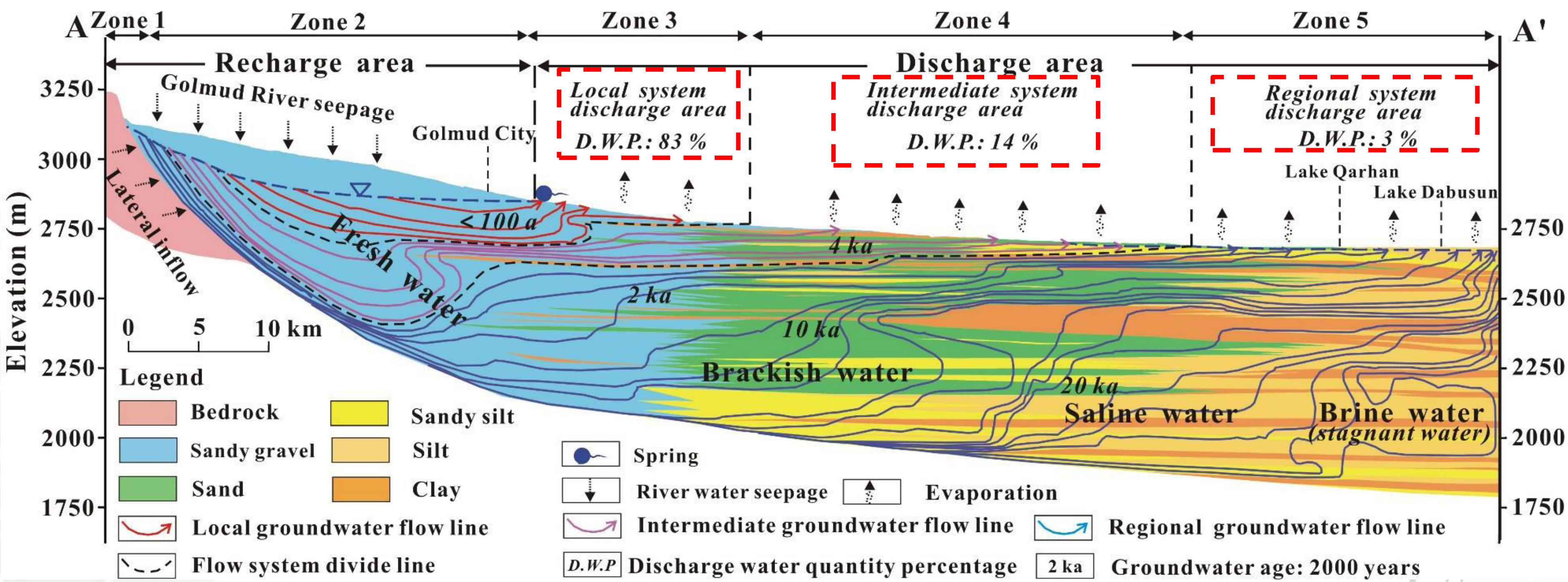
3、Results and Discussion

Scenario 1: Present status

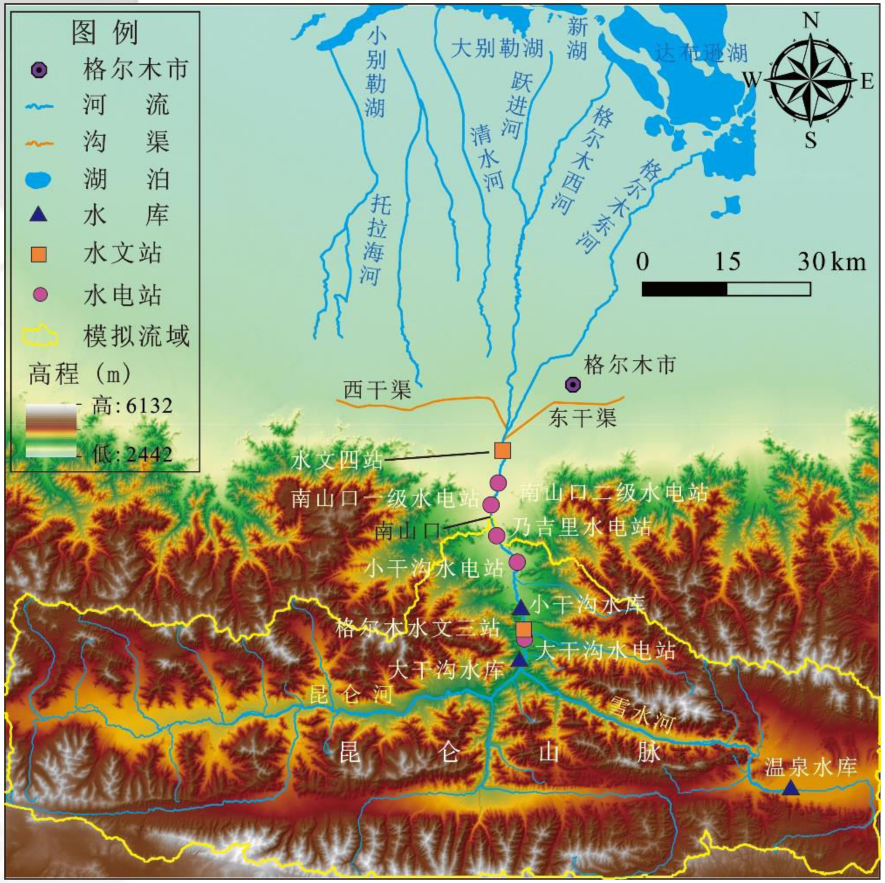
Groundwater flow lines are controlled by lithology

(especially the continuous aquitards at depths of 60 m, 290 m and 450 m).

Three different hierarchical groundwater flow systems were identified.

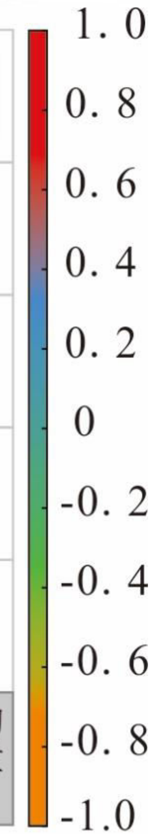


2、Methodology



SWAT model was established for the mountainous area.

年平均降水量(mm)					
0.34*	年平均气温(℃)				
0.14	-0.55**	年平均相对湿度(%)			
-0.26	-0.32	-0.003	平均风速(m/s)		
-0.41*	-0.10	-0.23	-0.01	年平均日照时数(h)	
0.83**	0.44**	0.12	-0.33*	-0.30	年平均径流量(m^3/s)



* 表示在0.05级别（双尾），相关性显著
**表示在0.01级别（双尾），相关性显著

Correlation between meteorological parameters and the runoff river water quantity at the mountain pass

2、Methodology

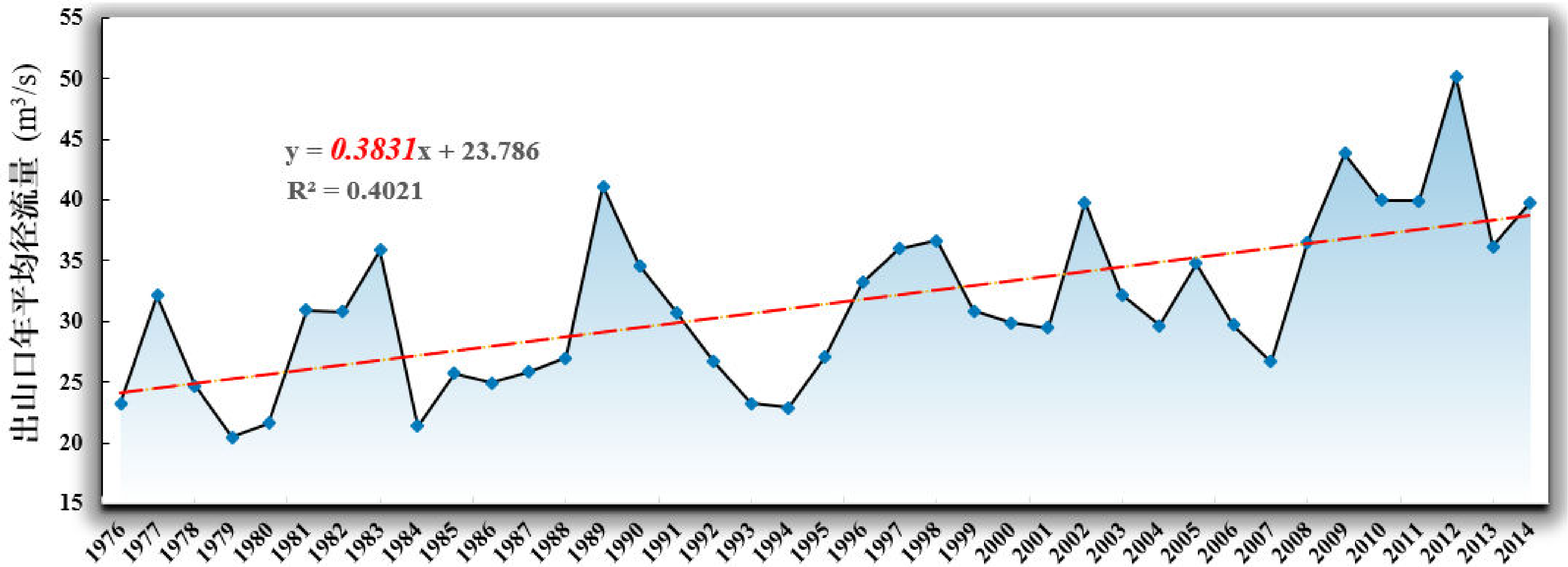


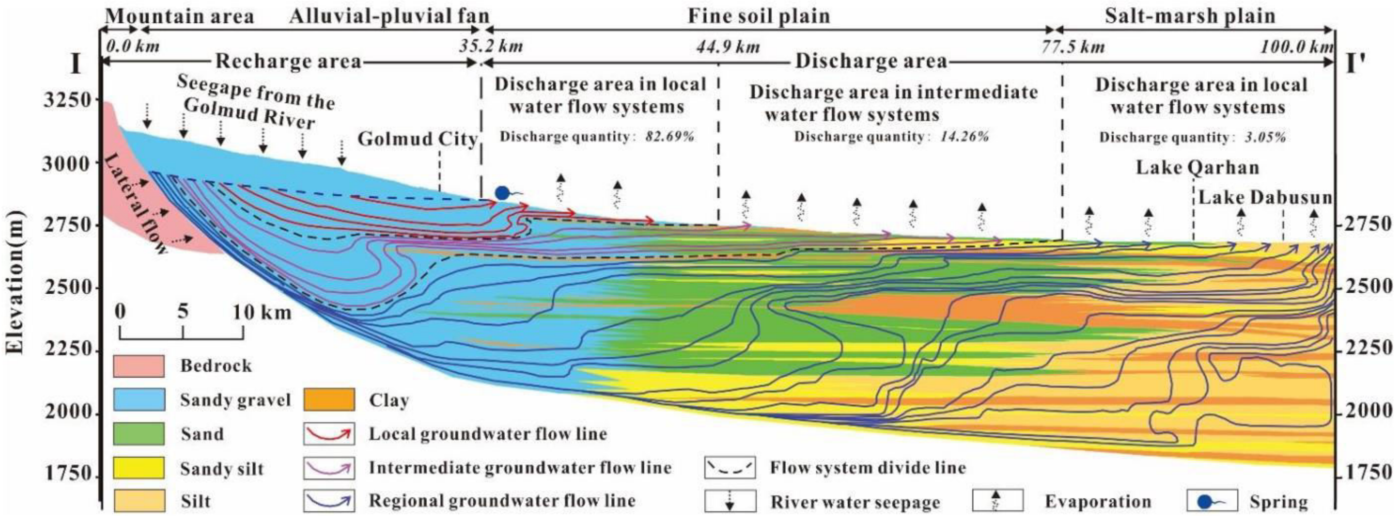
TABLE 1 Meteorological and hydrological scenarios for groundwater modelling.

Scenario	Years	Temperature /℃	Potential evaporation	precipitation	Melt water	River runoff flux	River seepage quantity
Scenario 1	2016	6.85	100%	100%	100%	100%	100%
Scenario 2	2100	9.06	52%	110.35%	160%	140.14%	130.78%

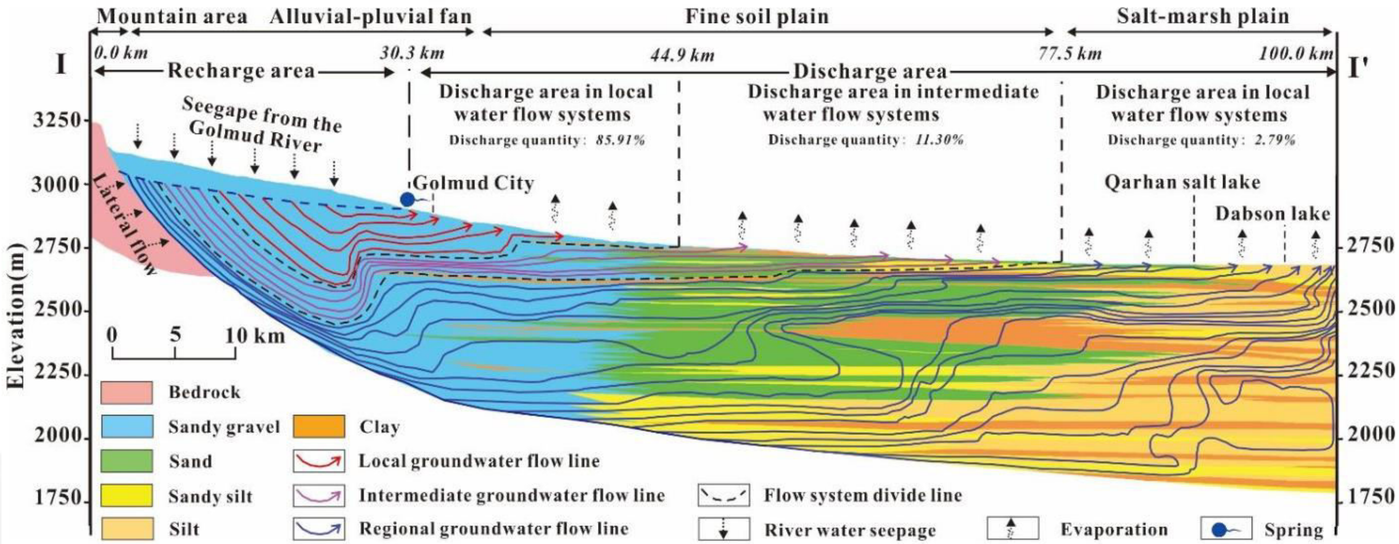
Scenario 1: Present status ; Scenario 2: climate warming

3、Results and Discussion

Scenario 1: Present status



Scenario 2: climate warming



3、Results and Discussion

TABLE 3 The discharge of various groundwater flow systems of the profile.

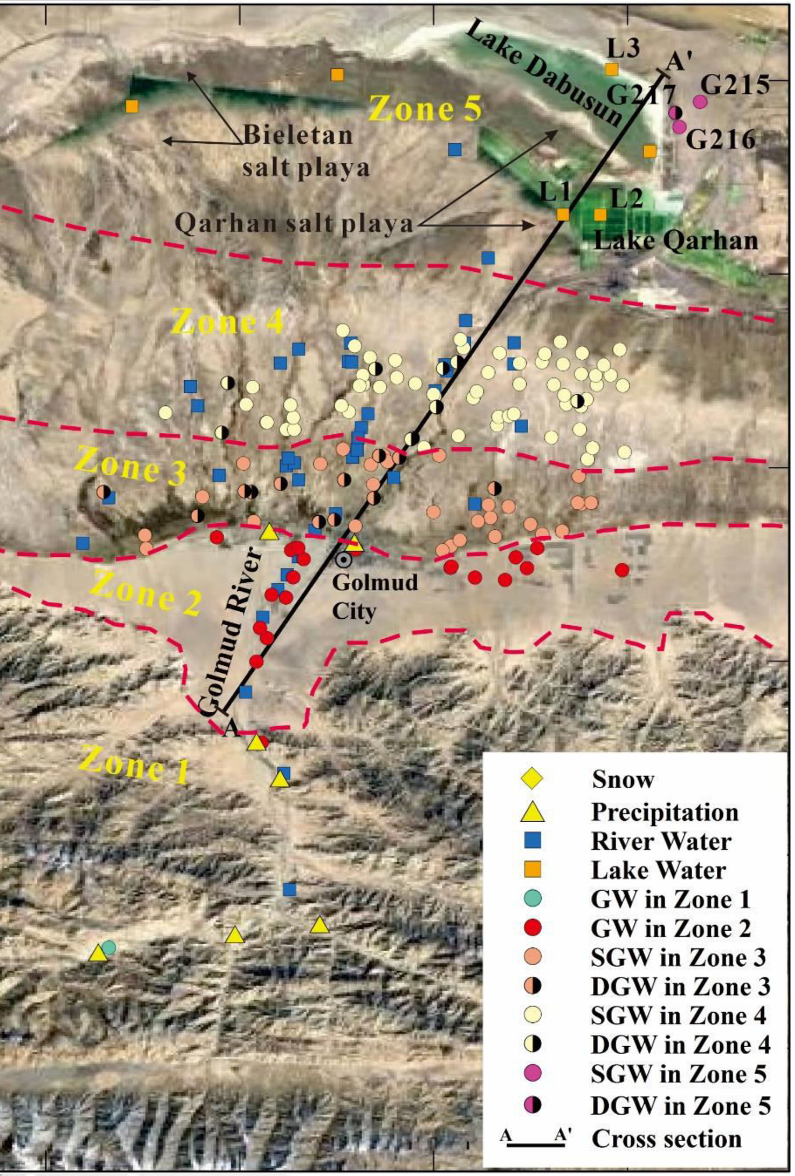
Groundwater flow system	*Scenario 1: Present status*		*Scenario 2: climate warming*	
	Discharge water quantity / $m^3 \cdot d^{-1}$	percentage / %	Discharge water quantity / $m^3 \cdot d^{-1}$	percentage / %
Local system	112.16	82.69	152.40	85.91
Intermediate system	19.34	14.26	20.05	11.30
Regional system	4.14	3.05	4.95	2.79

3、Results and Discussion

TABLE 4 Groundwater balance of the modeled domain.

		Scenario 1: Present status		***Scenario 2: climate warming***	
		Water quantity / $m^3 \cdot d^{-1}$	Percentage / %	Water quantity / $m^3 \cdot d^{-1}$	Percentage / %
Recharge	River seepage	135.61	99.97	177.35	99.98
	Bedrock lateral inflow	0.04	0.03	0.04	0.02
	Total	135.65	100.00	177.39	100.00
Discharge	Spring	-78.59	57.94	-120.00	67.65
	Evaporation	-35.08	25.86	-35.10	19.79
	Pumping	-20.65	15.22	-20.65	11.64
	Outflow into the lake	-1.33	0.98	-1.65	0.93
	Total	-135.65	100.00	-177.39	100.00

3、Results and Discussion



pH

Surface water:

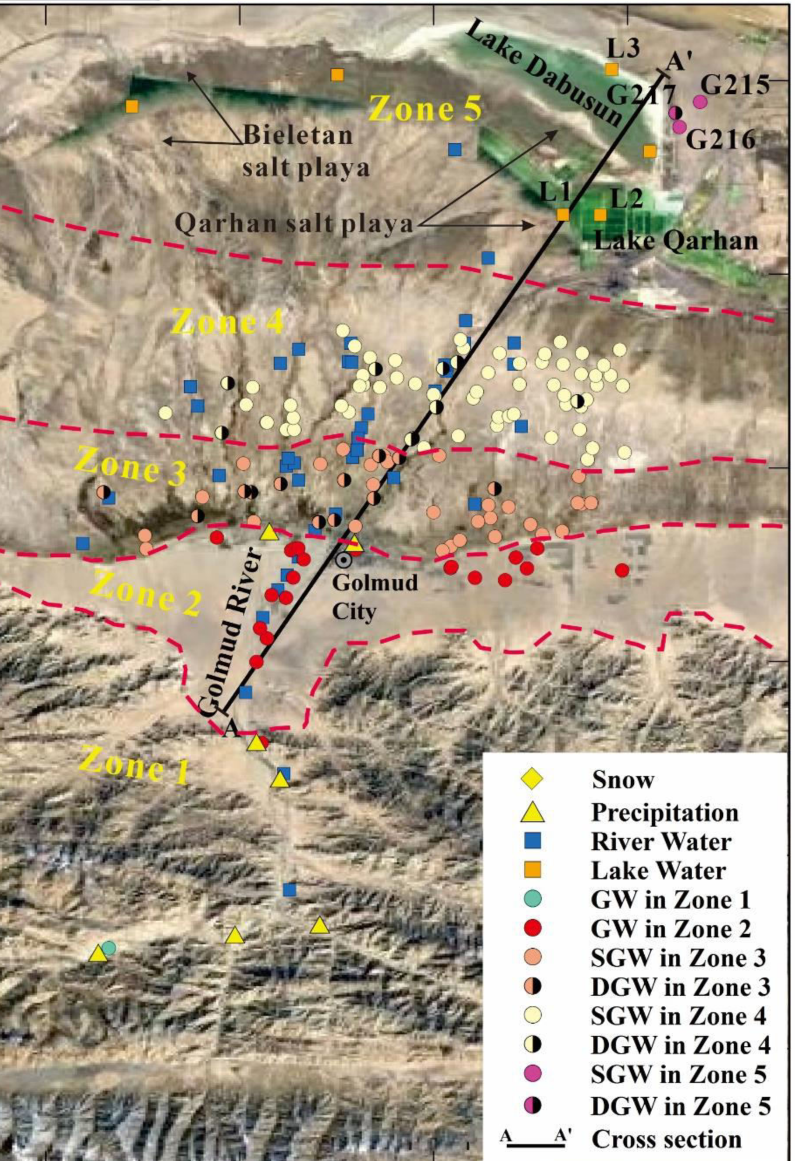
River waters (Zone 1~5): *slightly alkaline (pH: 7.94~ 9.45).*

Lake waters (Zone 5): *slightly alkaline (estuary) (pH: 8.98) to slightly acidic (pH: 6.03~6.28).*

Groundwater:

Groundwater: slightly alkaline to slightly acidic (*pH: 9.34 to 6.03*).

3、Results and Discussion



Total dissolved solids (TDS)

Surface water:

River waters (Zone 1~5):

393 to 2,319 mg/L

Lake waters (Zone 5):

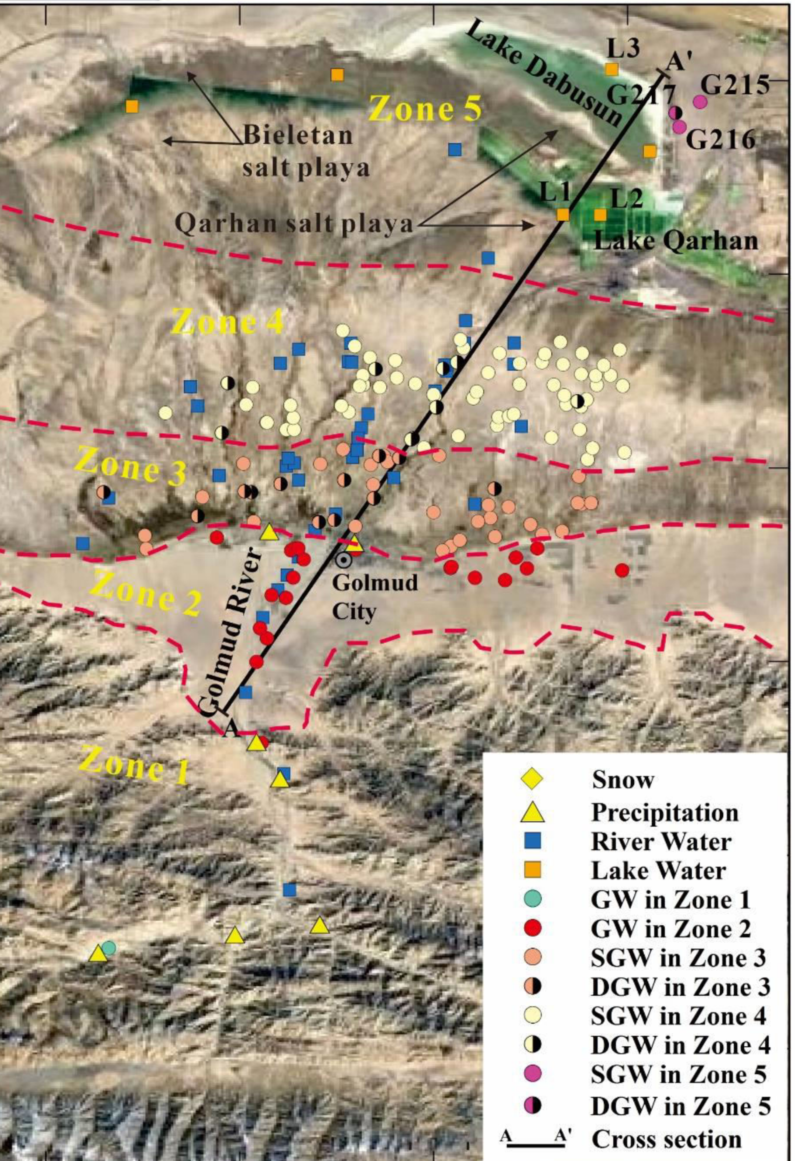
10,937~ 403,758 mg/L.

Groundwater:

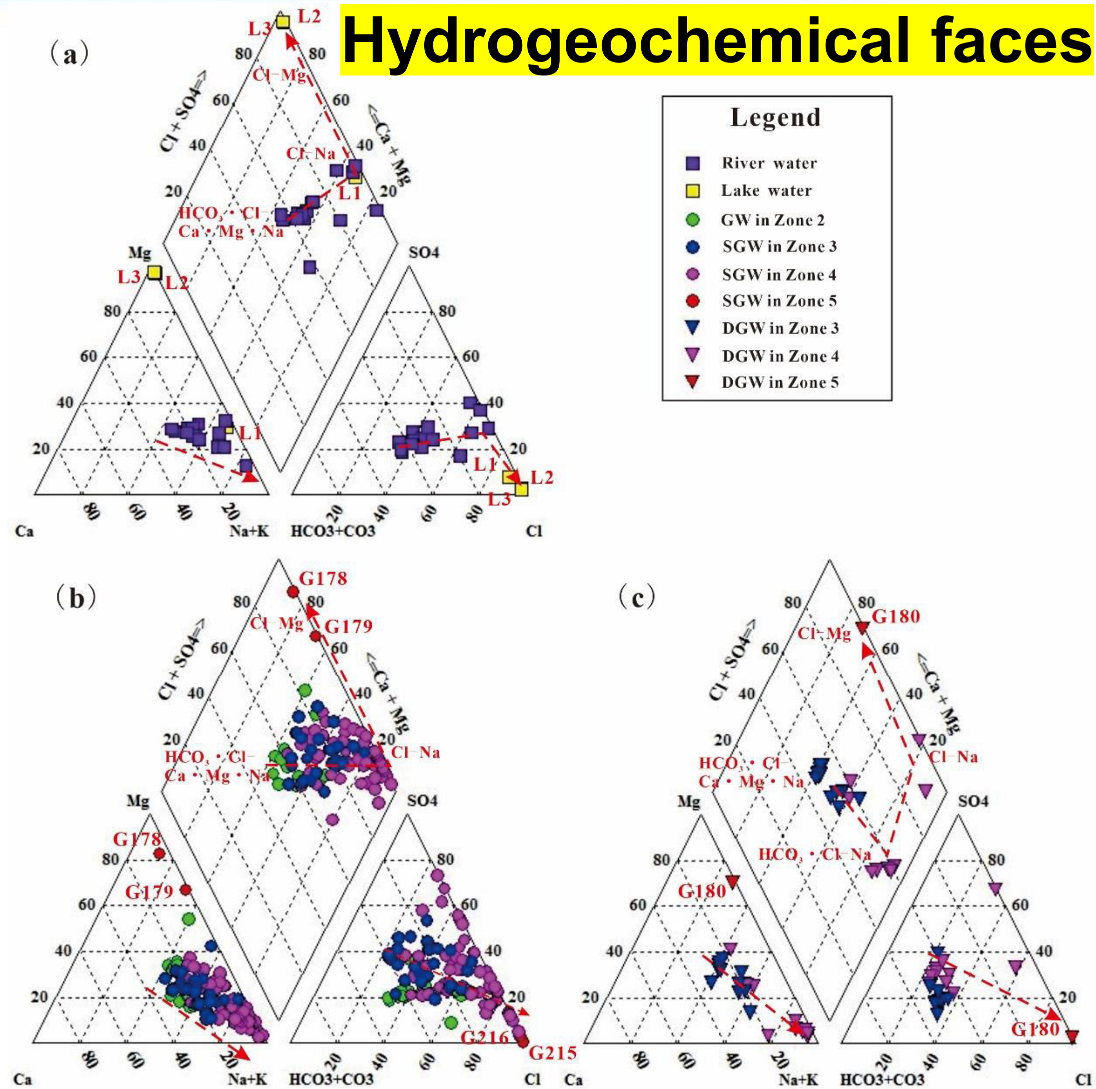
Gradually vary from fresh water to salt water along the groundwater path.

Deep GW is fresher than shallow GW in the middle and upper stream area.

3、Results and Discussion

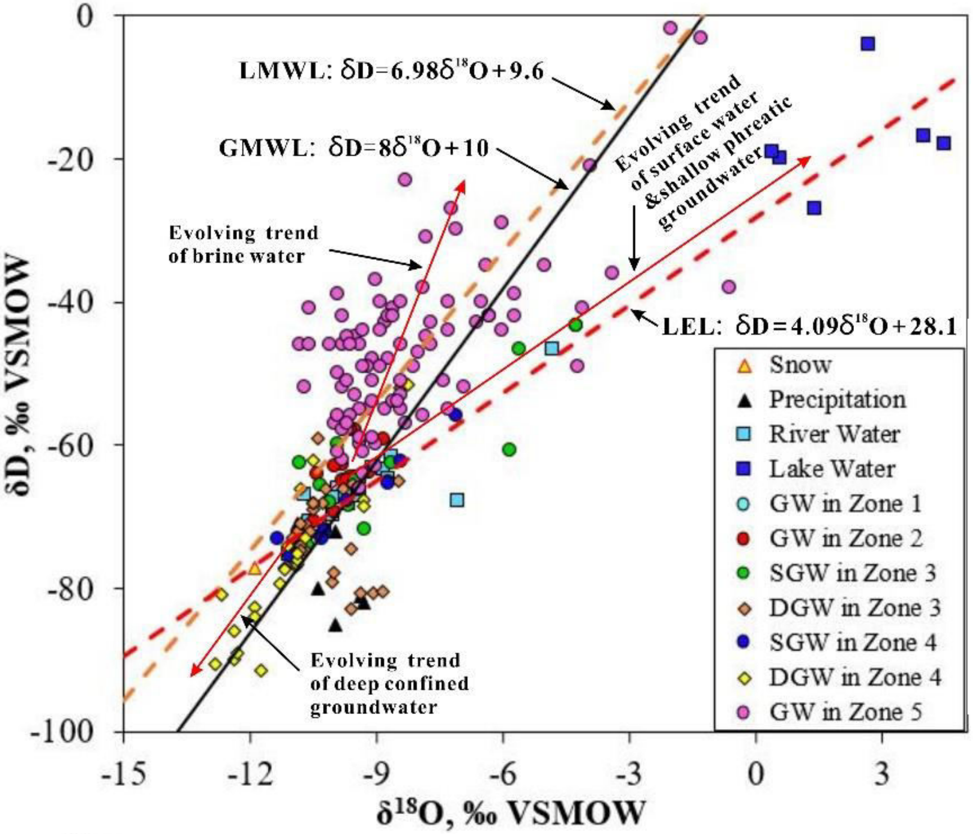


Hydrogeochemical faces



(a) surface waters; (b) shallow phreatic groundwaters; (c) deep confined groundwaters

cussion

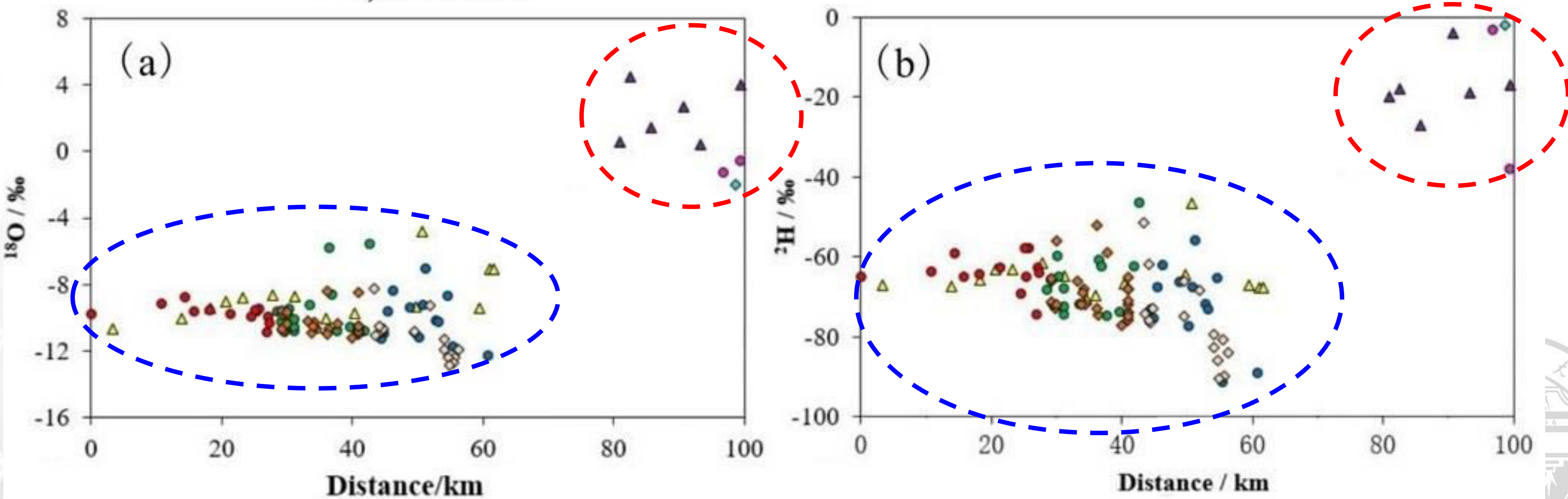


RW & GW (Zone 1~4):

Precipitation and melt water.

Brines:

Maybe multi-recharge sources.



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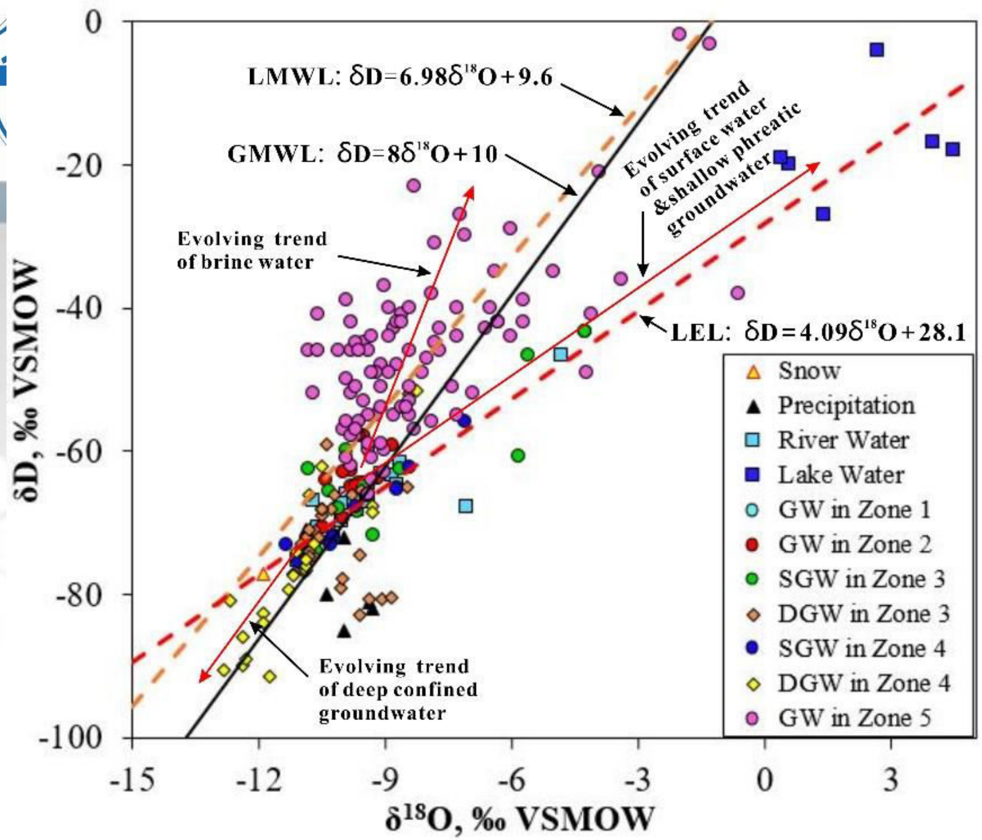
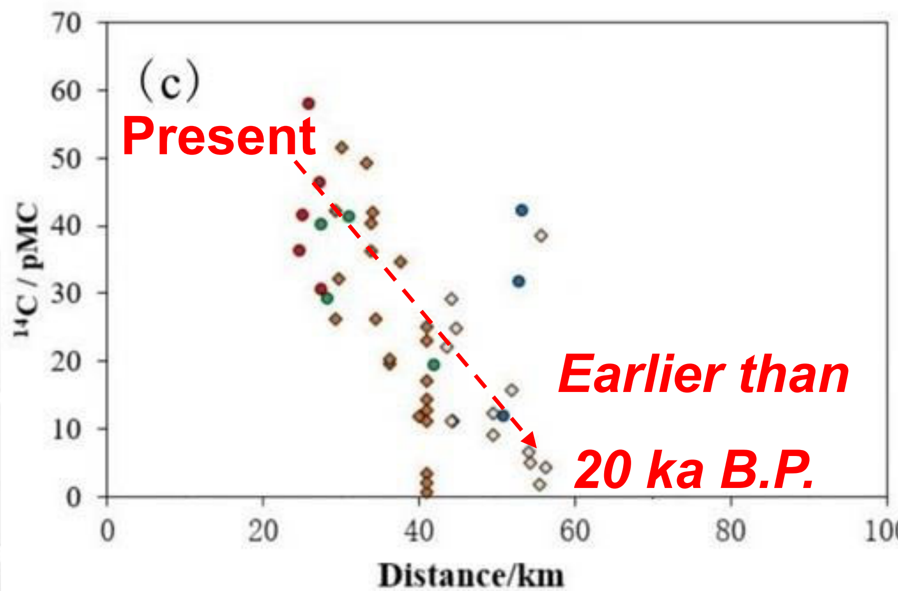


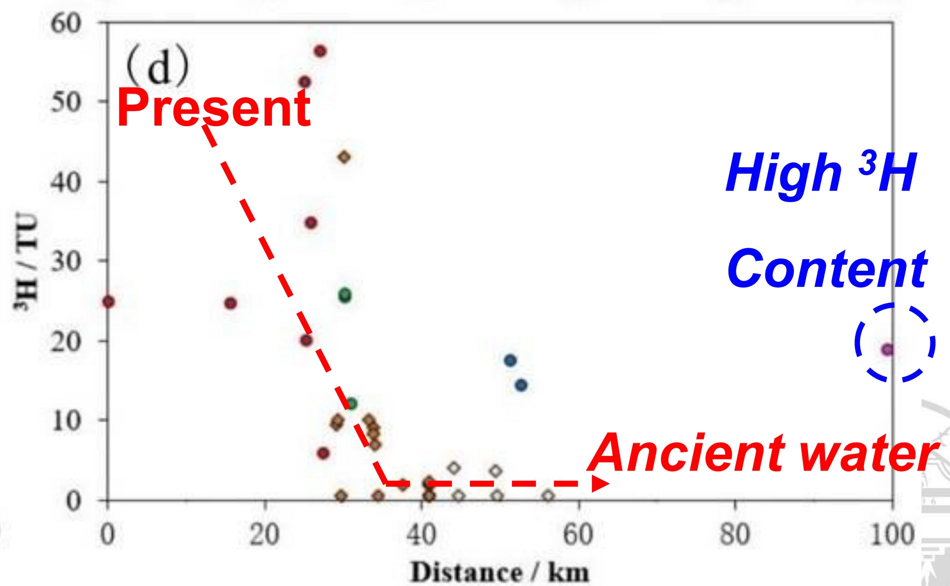
Deep confined water

modern to ancient water

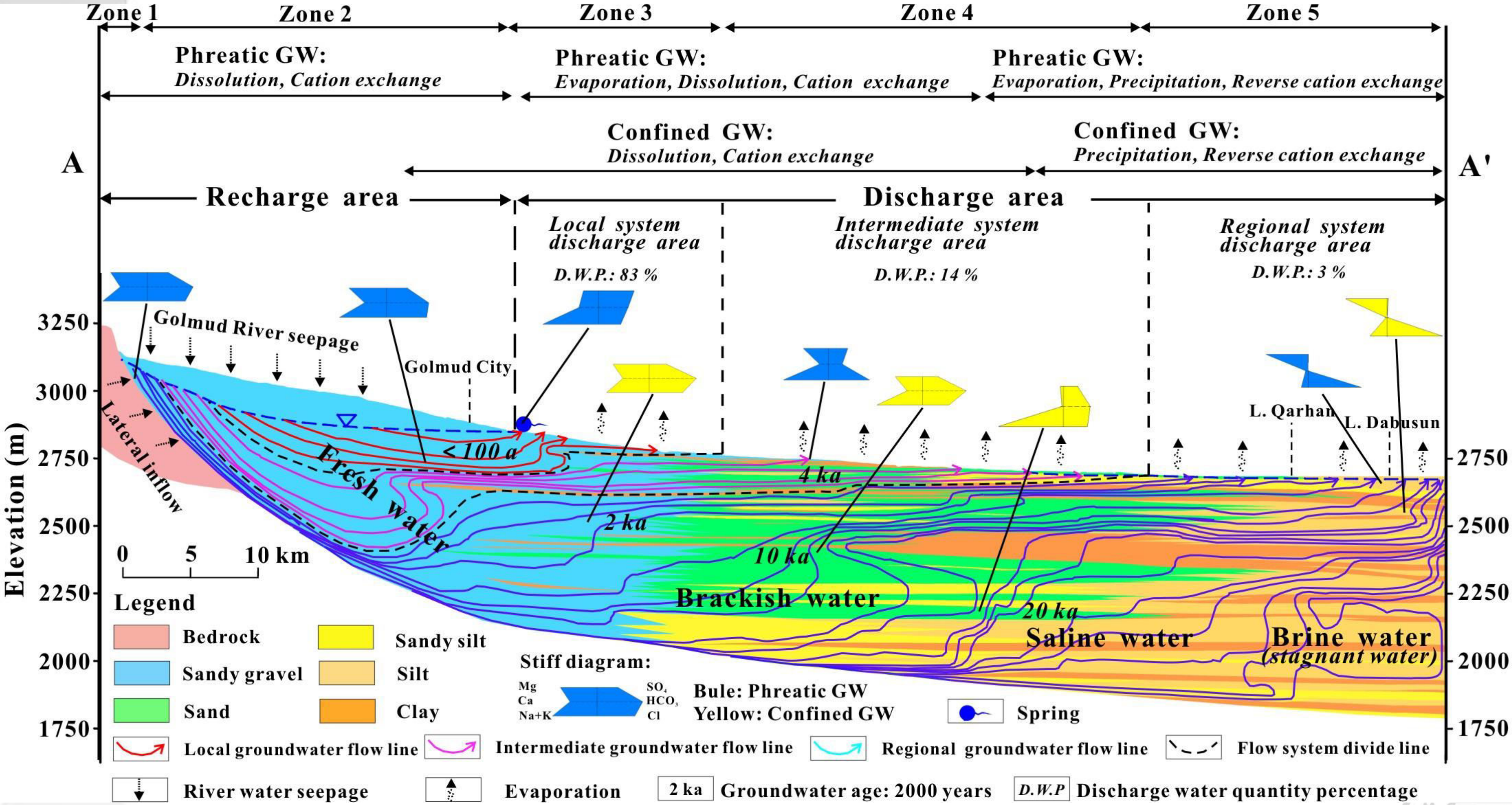
Shallow Groundwater

mixing water



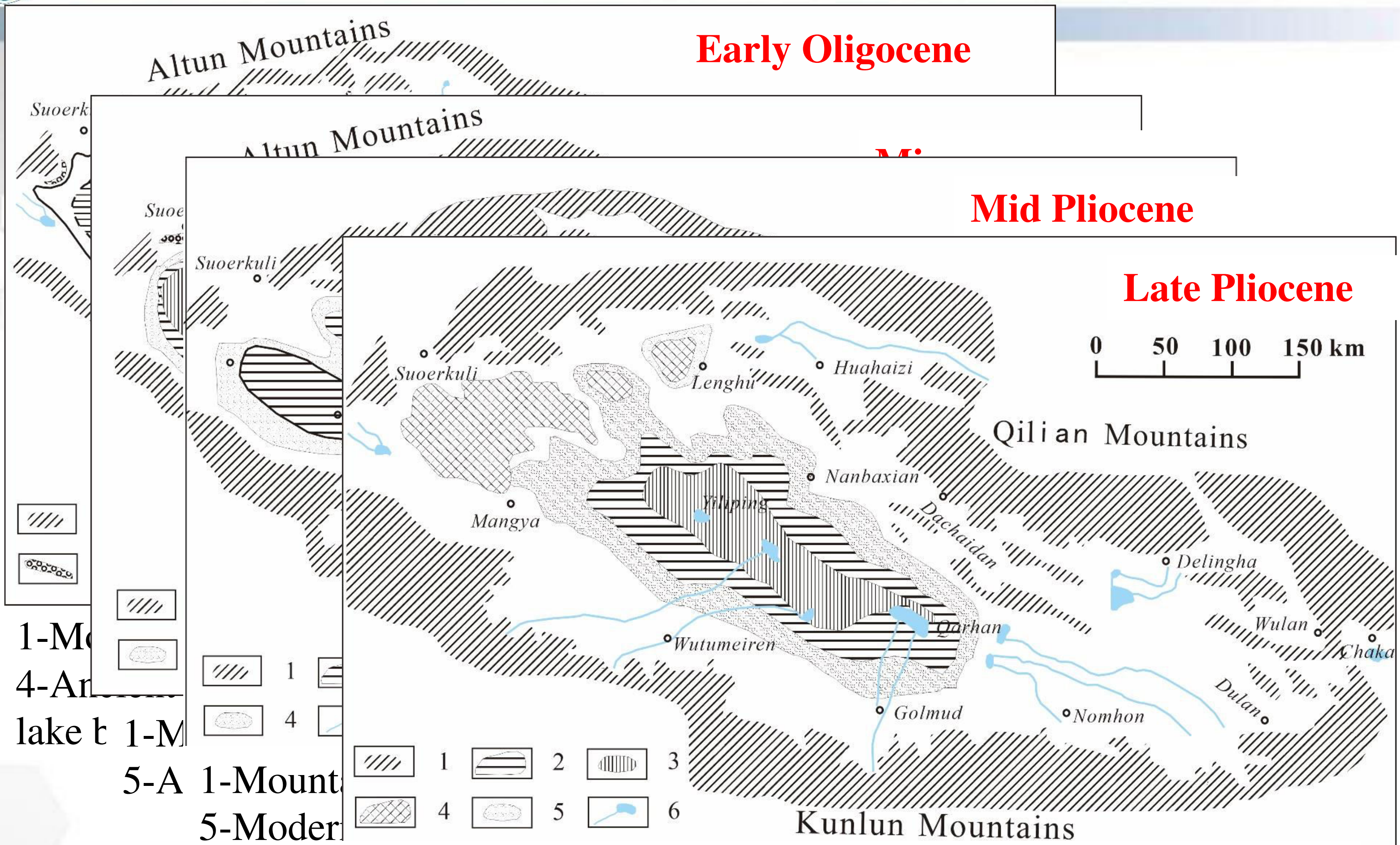


3、Results and Discussion



Conceptual model of groundwater flow and hydrochemical evolution

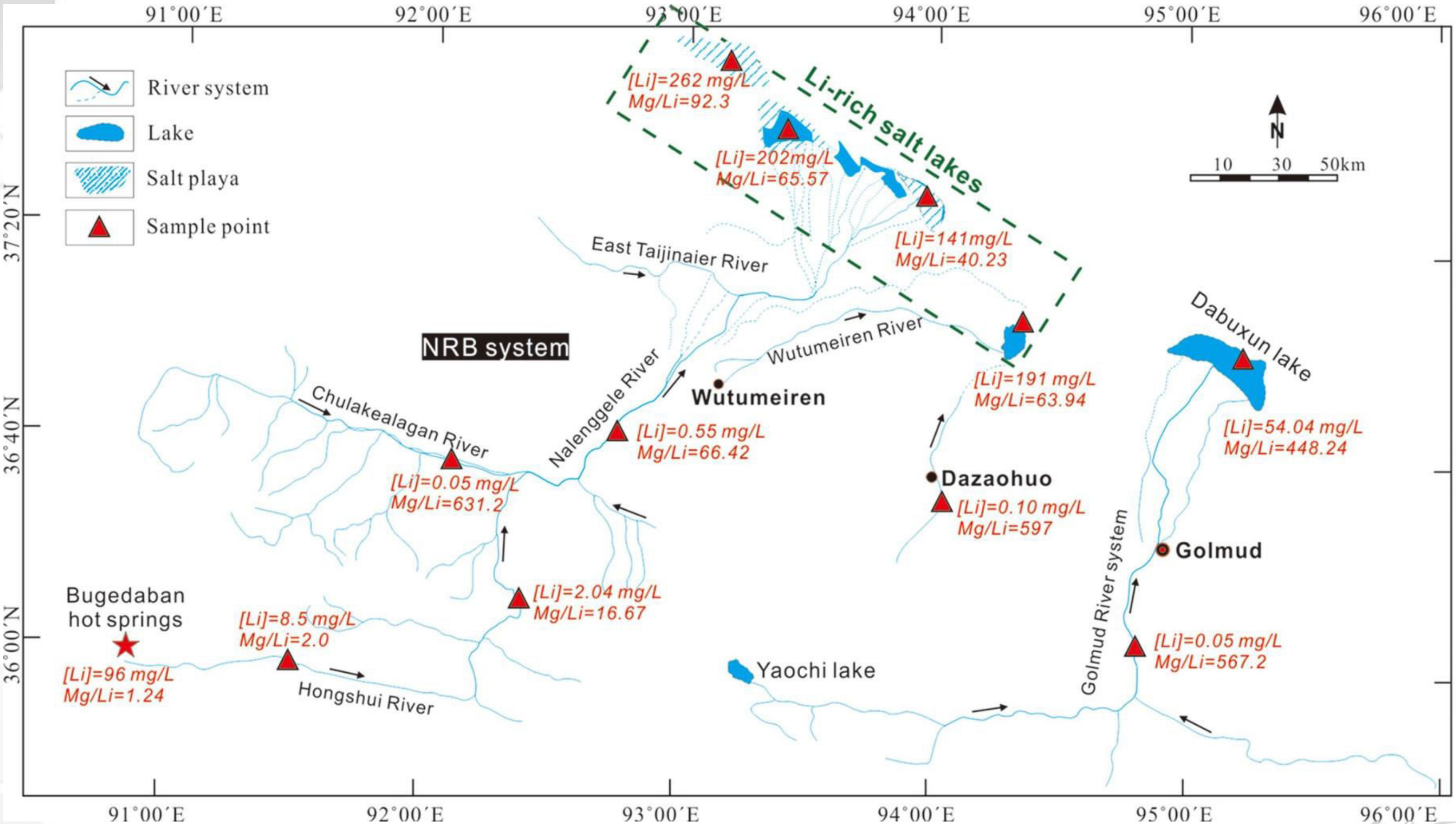
3、Results and Discussion



1-Mountain area; 2-Shallow lake; 3-Deep lake; 4-Salt playa;
5-Lakeside; 6-Modern river and lake

Brines from ***Ancient salt water migrated from the western Basin.***

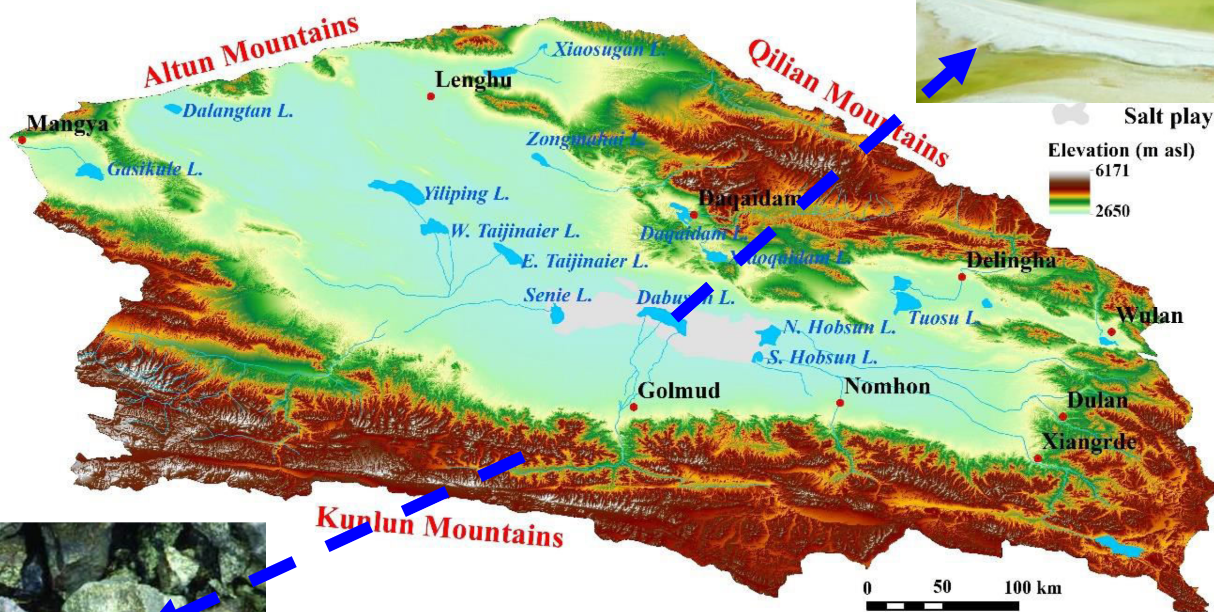
3、Results and Discussion



Lithium is also enriched in modern waters. **(also Boron)**

3、Results and Discussion

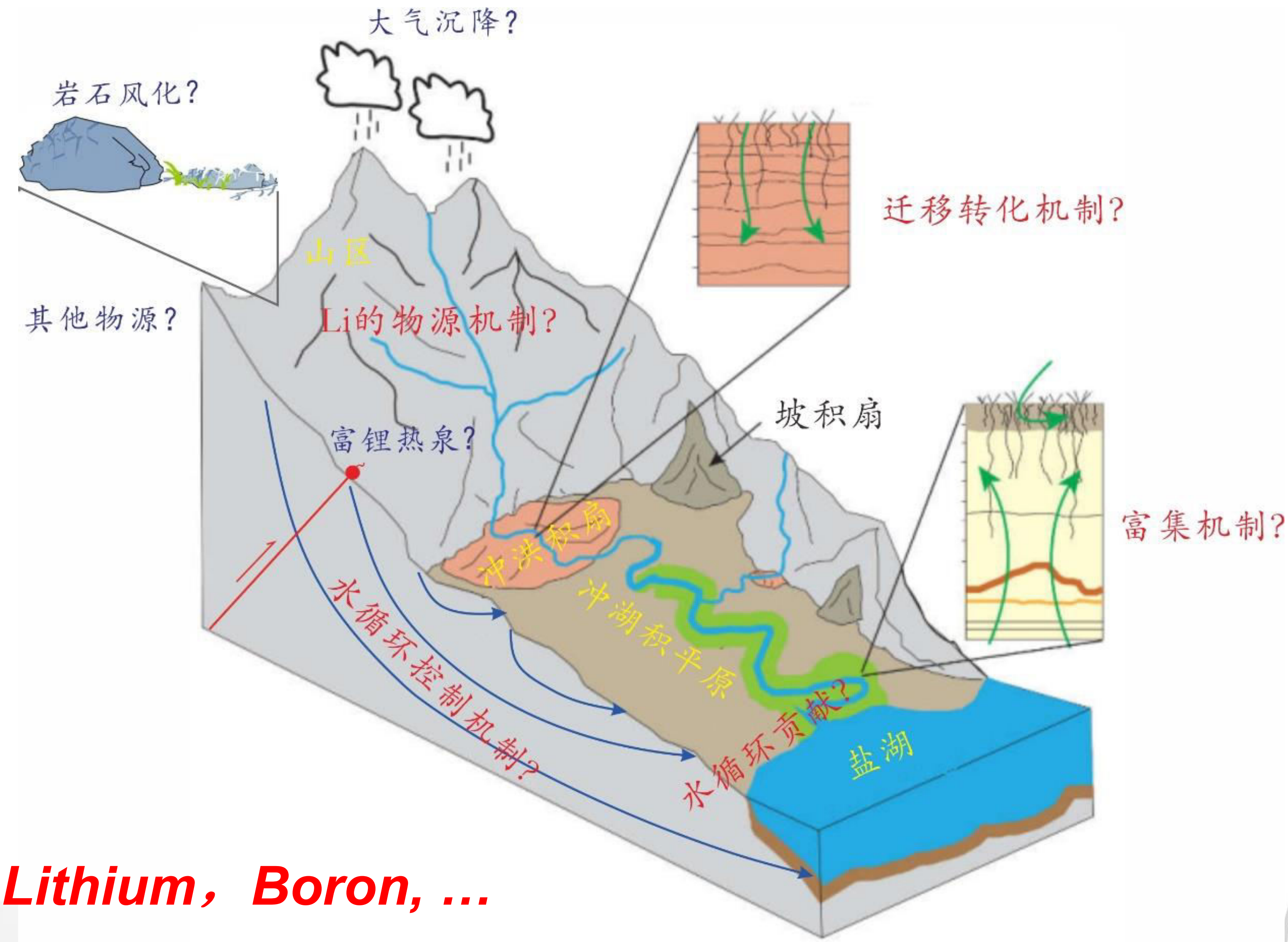
Lithium，Boron, …



So what is the relation?

How about their contribution?

Future work



Lithium，Boron, …

4、Concluding Remarks

- River seepage at the piedmont is the driving force of groundwater flow system development and evolution in hyper-arid inland basin.
- Groundwater circulation is the key factor determining water resources availability, water hazards, and contributing to the salt lake resources.
- Climate warming would pose significant influences on groundwater flow systems, especially the local ones.

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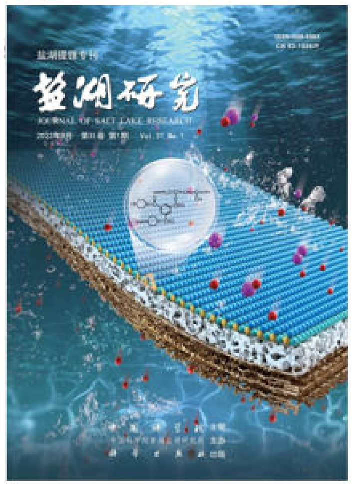

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