中国地质调查局水文地质环境地质调查中心
CENTER FOR HYDROGEOLOGY AND ENVIRONMENTAL GEOLOGY, CGS

深部咸水层二氧化碳地质储存潜力评价及场地选址方法

CO_2 Geological Storage Potential Evaluation and Site Selection Method in Deep Saline Aquifers

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Center for Hydrogeology and Environmental geology

China Geological Survey

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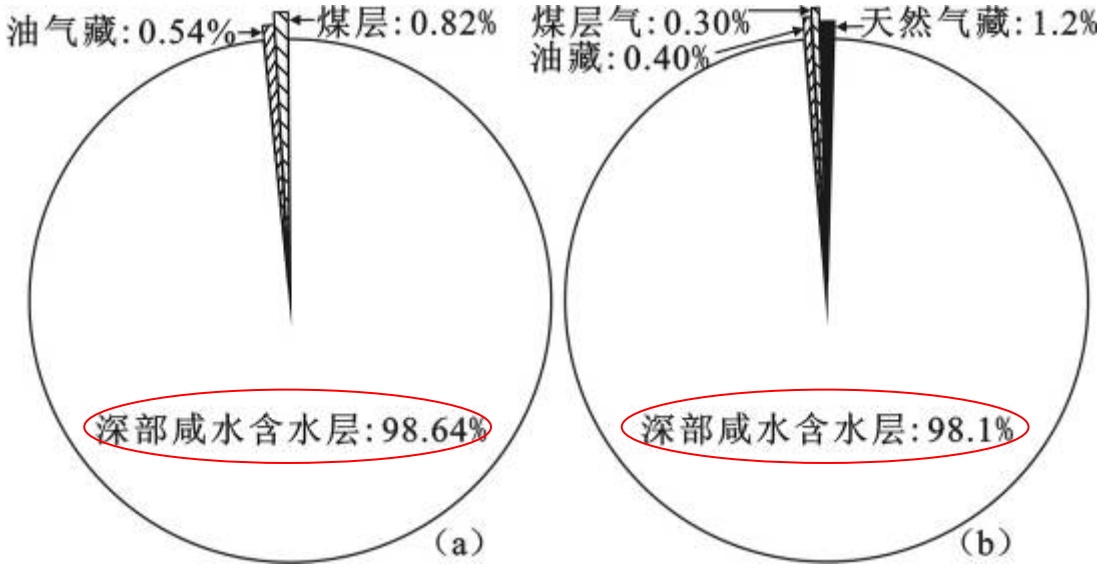
汇报提纲
Outline

- 研究背景
- *Background*
- 深部咸水层CO_2地质储存属性界定
- *Attribute definition of CO_2 geological storage in deep saline aquifers*
- 选址原则
- *Site selection principles*
- 选址阶段划分
- *Site selection stages division*
- 选址指标体系及评价方法
- *Site selection index system and assessment method*

一、研究背景 Background

•2005，2010年，国土资源系统先后对中国CO_2地质储存潜力进行了估算，结果显示，深部咸水含水层是开展CO2地质储存的主力。



- *Deep saline aquifers are widely distributed in China with large thickness.*
- *The Ministry of Land and Resources carried out CO_2 geological storage potential evaluation in 2005 and 2010, the CO_2 storage total reserves in deep saline aquifers accounts for more than 98% of three modes, which suggested that deep saline aquifers are the main force to carry out CO_2 geological storage.*

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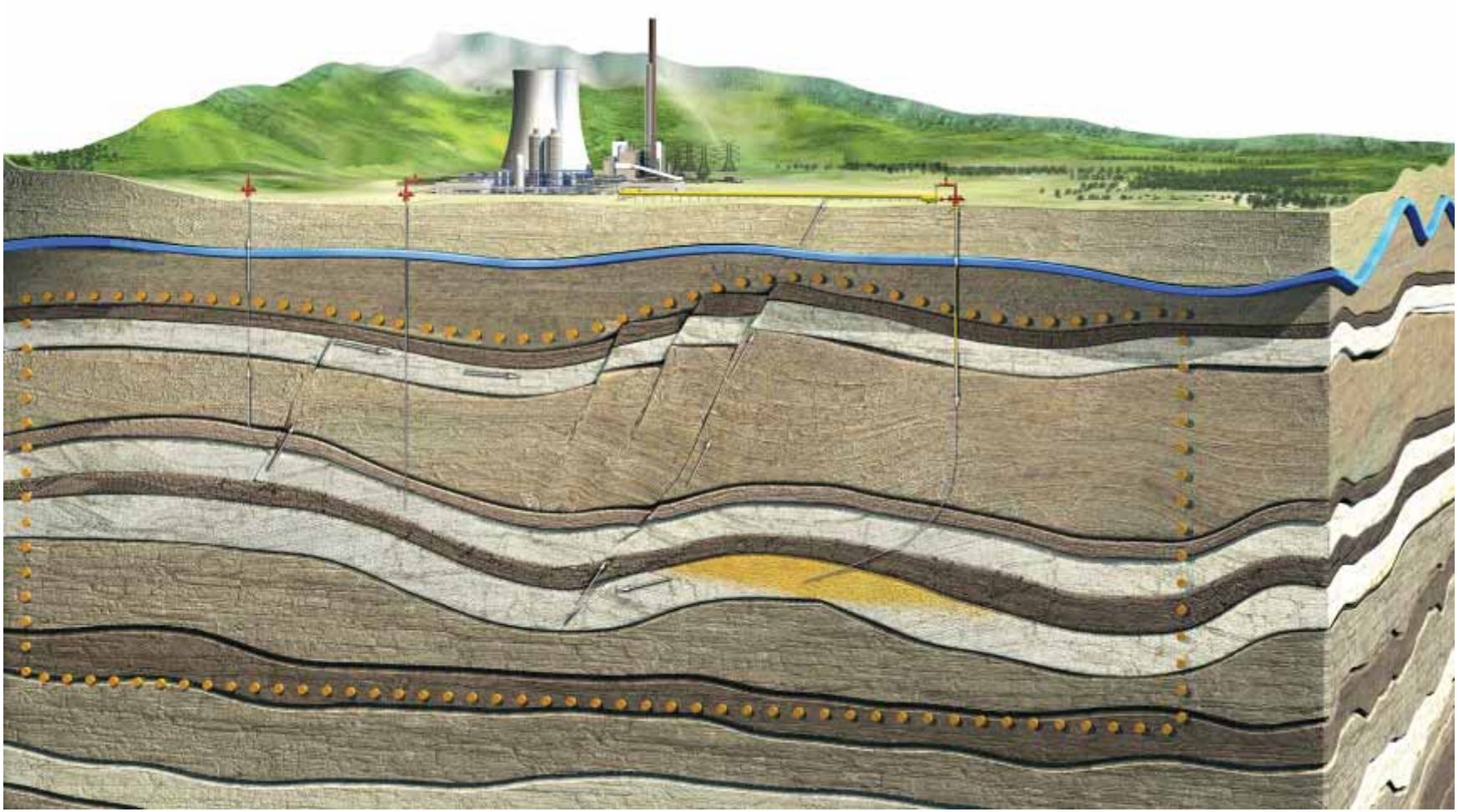
二、 适合CO_2地质储存的深部咸水层定义

Attribute definition of CO_2 geological storage in deep saline aquifers

- 顶板埋深在800m以下，具有一定分布面积，厚度大，含水介质孔隙度、渗透率高;
- 顶、底板为隔水性良好、大厚度、稳定的泥、膏岩类隔水层/盖层；且无贯通性的盖层裂缝和活断裂发育，亦无畅通的废弃井；
- 矿化度介于10～50g/L之间，既不适合工农业利用，更不适合人类饮用，也达不到地下卤水液体矿矿化度要求，当今技术、经济条件下不可利用的深部咸水含水层。
- *Deep saline aquifers suitable for CO2 geological storage should be regional development and thick, with high porosity and permeability.*
- *And the reservoirs should be under 800m with good aquifuge, no caprock cracks, active faults, expedite abandoned wells, which could cause CO2 outbursting.*
- *Groundwater salinity of deep saline aquifers should be between 10-50g/L, could not be used for agriculture and industry in current technological and economic conditions, and no liquid resources.*

地下储存库示意图

schematic diagram of underground reservoirs



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三、场地选址原则

Site selection principles

- 目标储层具有可储存CO_2 30年以上、有效储存量大的原则
- 安全原则
- 经济原则
- 符合一般建设项目环境保护选址条件，不受外部不良地质因素影响的原则
- *Objective reservoirs should be great potential to store massive CO_2 for more than 30 years*
- *Be safe in a long term*
- *Accord with economical feasibility, less cost to carry out CO_2 storage*
- *Comply with the general conditions of construction project environmental protection sites, unaffect by external adverse geological factors*

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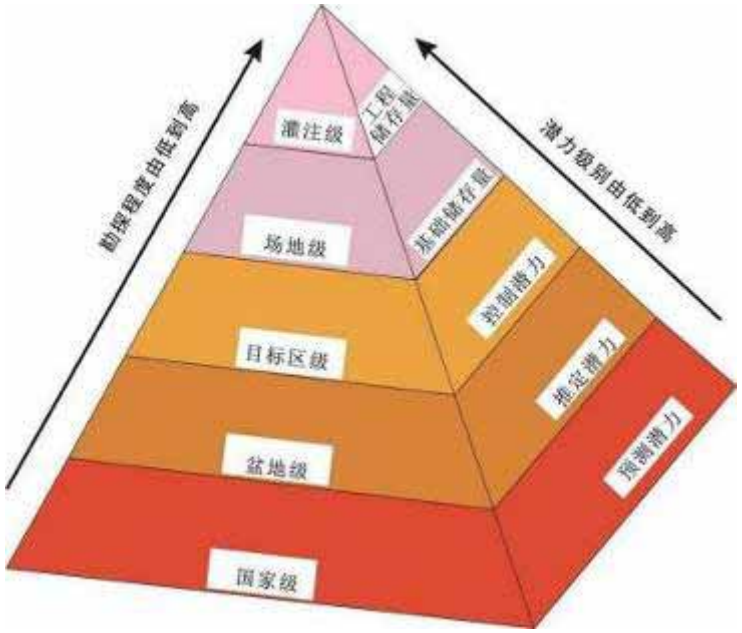
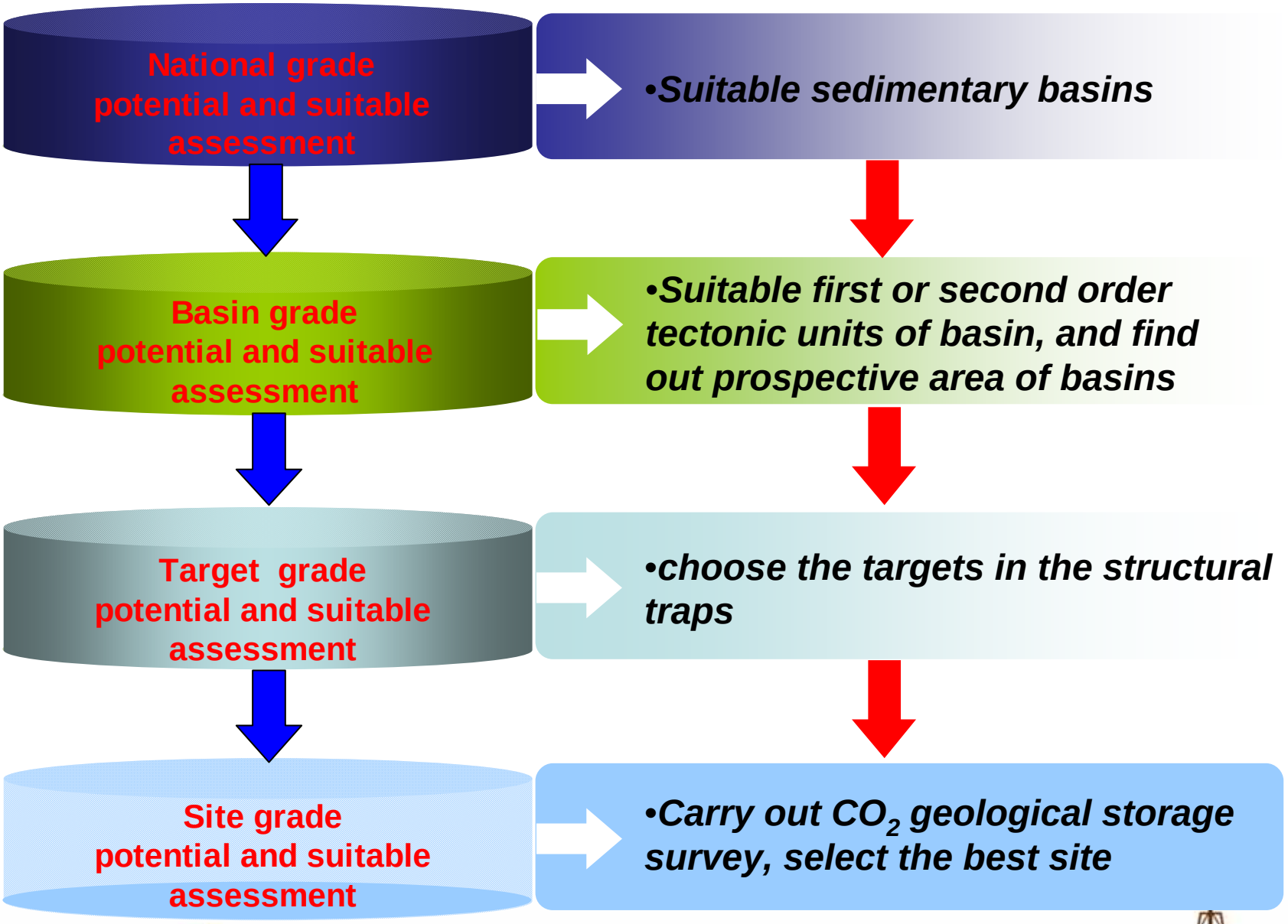
四、选址阶段划分
Site selection stages division



Stages	Potential levels	Level
National grade	Predicted potential	E
Basin grade	Inferred potential	D
Target grade	Controlled potential	C
Site grade	Basic capacity	B
Perfusion grade	Project capacity	A

- 选址的基本思路是基于从盆地—圈闭—注入层评价循序渐进开展选址工作的
- *The basic guideline is based on potential and suitable assessment on basins, traps and reservoirs in turn*

Stages	*Evaluation object*	*Level*	*Comprehensive evaluation*	
			Potential levels	*Purpose*
National grade potential evaluation	*A whole sedimentary basin*	*E*	*Predicted potential*	*Evaluate the suitability of every basin, find out the suitable basins*
Basin grade potential evaluation	*First order tectonic unit of basin*	*D*	*Inferred potential*	*Evaluate the suitability of structure units of basin, in order to find out the prospective area of basins*
Target grade potential evaluation	*Structural trap*	*C*	*Controlled potential*	*Establish the criteria of targets selection, and then choose the targets in the structural traps*
Site grade potential evaluation	*Geological storage site*	*B*	*Basic capacity*	*Carry out the site survey of CO2 geological storage, in order to guide the perfusion project design*
Perfusion grade potential evaluation	*Perfusion project*	*A*	*Project capacity*	*Carry out the monitoring of perfusion projects, evaluate the perfusion capacity and risk based on the CO2 perfusion*

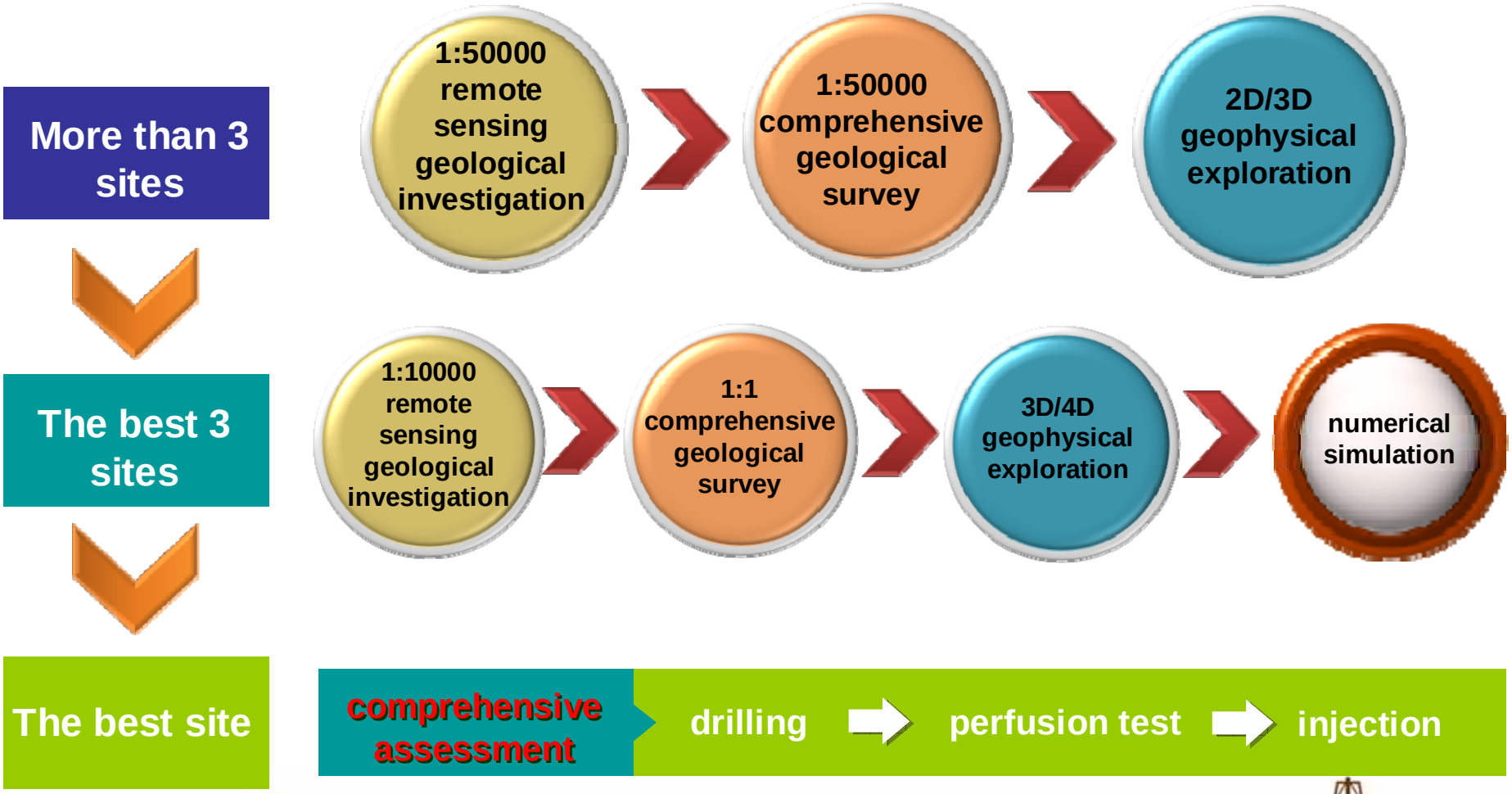

National grade potential and suitable assessment
•Suitable sedimentary basins
Basin grade potential and suitable assessment
•Suitable first or second order tectonic units of basin, and find out prospective area of basins
Target grade potential and suitable assessment
•choose the targets in the structural traps
Site grade potential and suitable assessment
•Carry out CO_2 geological storage survey, select the best site

国家级、盆地级、目标区级潜力评价工作都是建立在已有勘探资料的基础上

National, basin, target grades potential and suitable assessment are carried out at the basis of existing data

- ***潜力评价方法 (Potential evaluation method)***
  - 以碳封存领导人论坛（CSLF）计算公式为基础，结合中国沉积盆地地质背景，针对四种储存介质（深部咸水含水层、油田、气田和煤层）在不同的评价级别（E、D、C）下的CO_2地质储量的计算方法；
  - *Using formulas prepared by **Carbon Sequestration Leadership Forum (CSLF),** 2008*
- ***适宜性评价方法 (Suitable assessment method)***
  - 在以往研究基础上，确定了CO_2地质储存的适宜性评价方法及评价指标体系——层次分析基础上的综合评价方法；
  - *Modified by Bachu(2003), Oldenburg（2008）,GA(2009) and SHEN Pingping(2009), determined the suitable assessment method and indexes system —— Comprehensive scoring method based on **Analytic Hierarchy Process** (AHP)*

Site grade potential and suitable assessment at the basis of geological survey



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China Australia Geological Storage of CO_2

中澳二氧化碳地质封存

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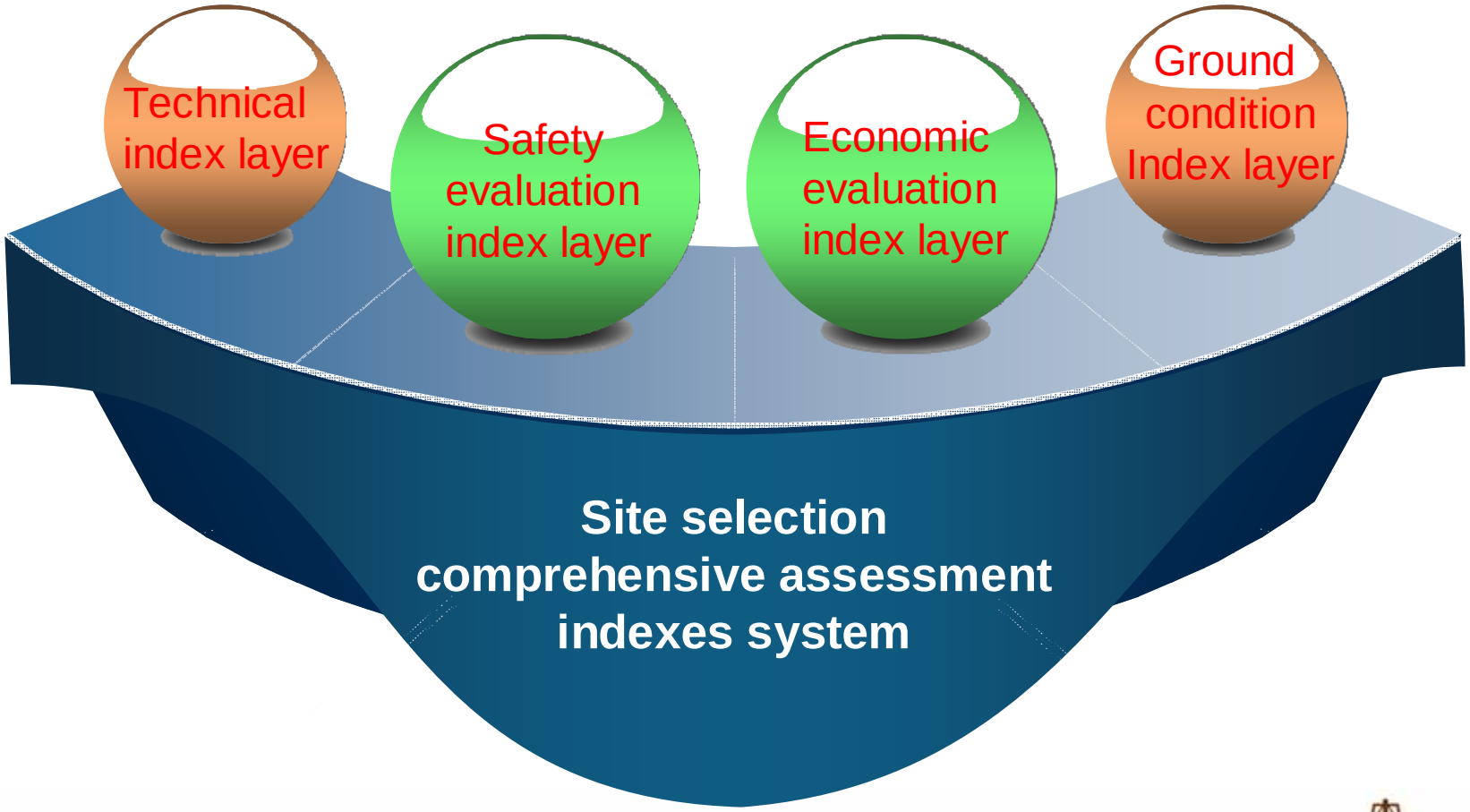
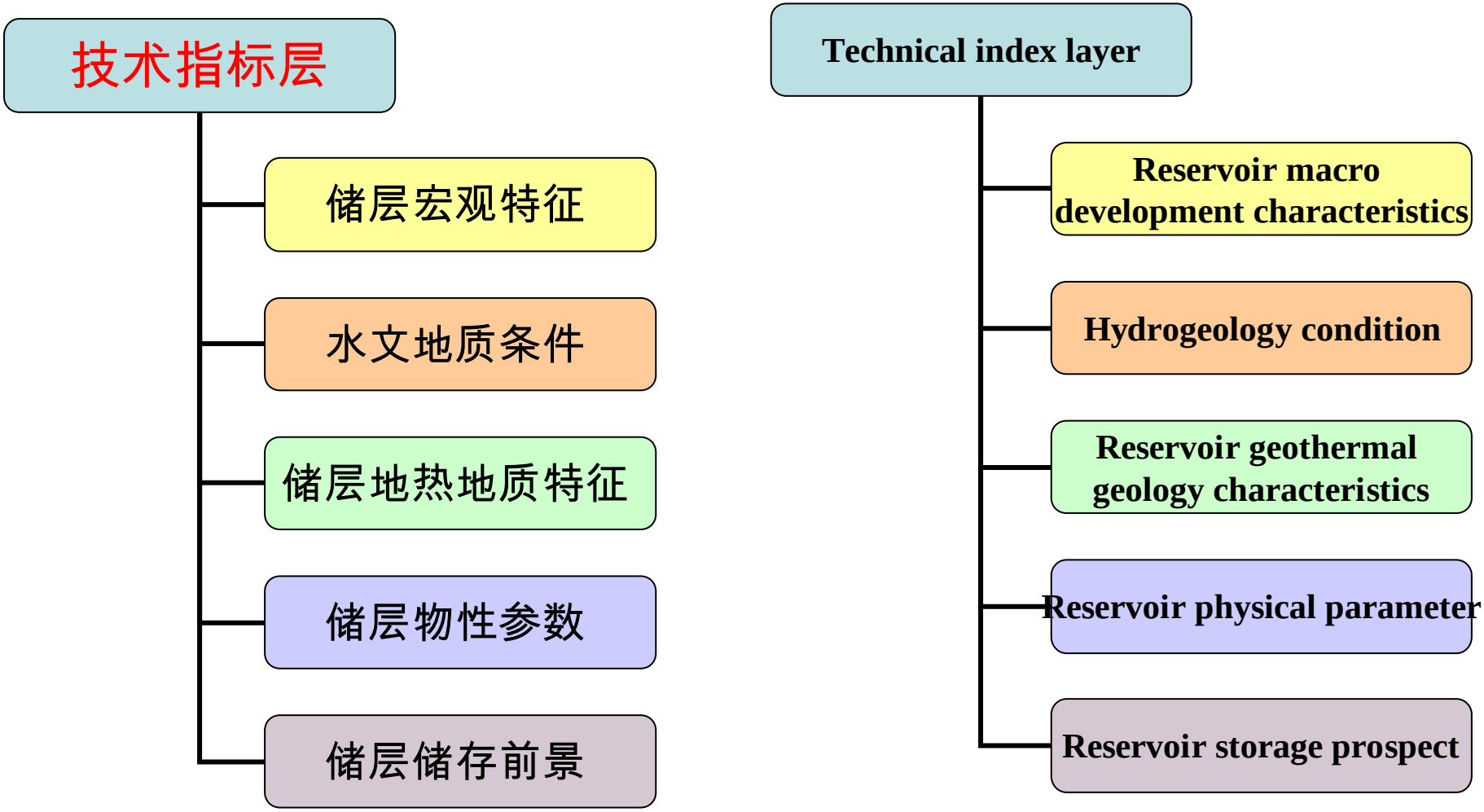
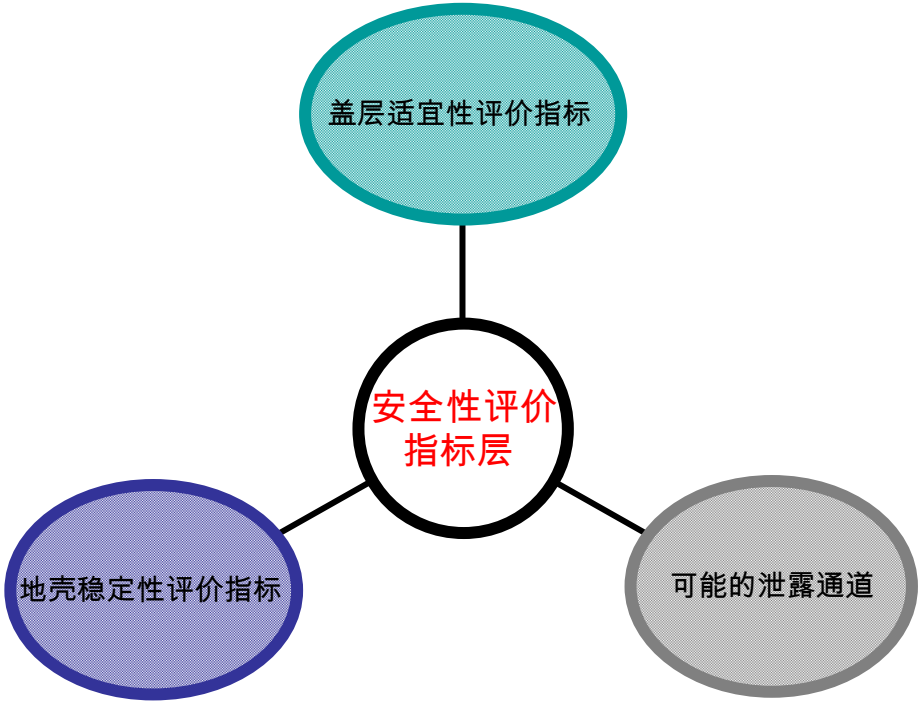
Site selection indexes system with multi-factors ranking for CO_2 geological storage in deep saline

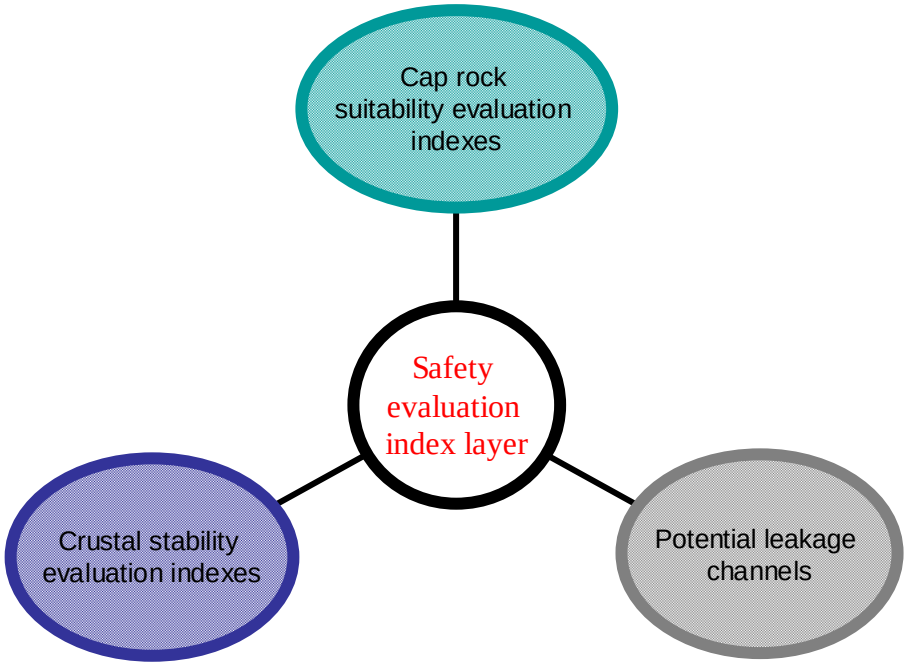



技术指标层
储层宏观特征
水文地质条件
储层地热地质特征
储层物性参数
储层储存前景
Technical index layer
Reservoir macro development characteristics
Hydrogeology condition
Reservoir geothermal geology characteristics
Reservoir physical parameter
Reservoir storage prospect

技术指标层	指标亚层		具体指标	排序标准			
				好		一般	差
	深部咸水含水层储层系统选址指标亚层	储层宏观特征	埋深（m）	800～3500		>3500	<800
			地层组合与砂厚比（%）	砂岩（碳酸岩盐）夹泥岩、层状分布； 砂厚比>60%		砂泥岩互层或泥岩夹砂岩/砂厚比20%～60%	泥岩夹砂岩； 砂厚比<20%
		水文地质条件	水动力作用	水力封闭作用		水力封堵作用	水力运移逸散作用
			水头状态（m）	低于场地地面		大体与场地地面一致	大于场地地面
			矿化度（g/L）	10.0～50.0		3.0～10.0	<3.0、>50.0
		储层地热地质特征	地表温度（℃）	<-2		-2～10	>10
			地温梯度（℃/h）	<2		2～4	>4
			大地热流值（HFU）	<54.5		54.5～75	>75
		储层物性参数	孔隙度（%）	砂岩	>15	15～10	<10
				碳酸盐岩	>12	12～4	<4
			渗透率(×10-3μm2)	砂岩	>50	50～10	<10
				碳酸盐岩	>10	10～5	<5
			非均质性（渗透率变异系数）	<0.5		0.5～0.6	>0.6
		储层储存前景	有效储存量（万t）	>900		900～300	<300

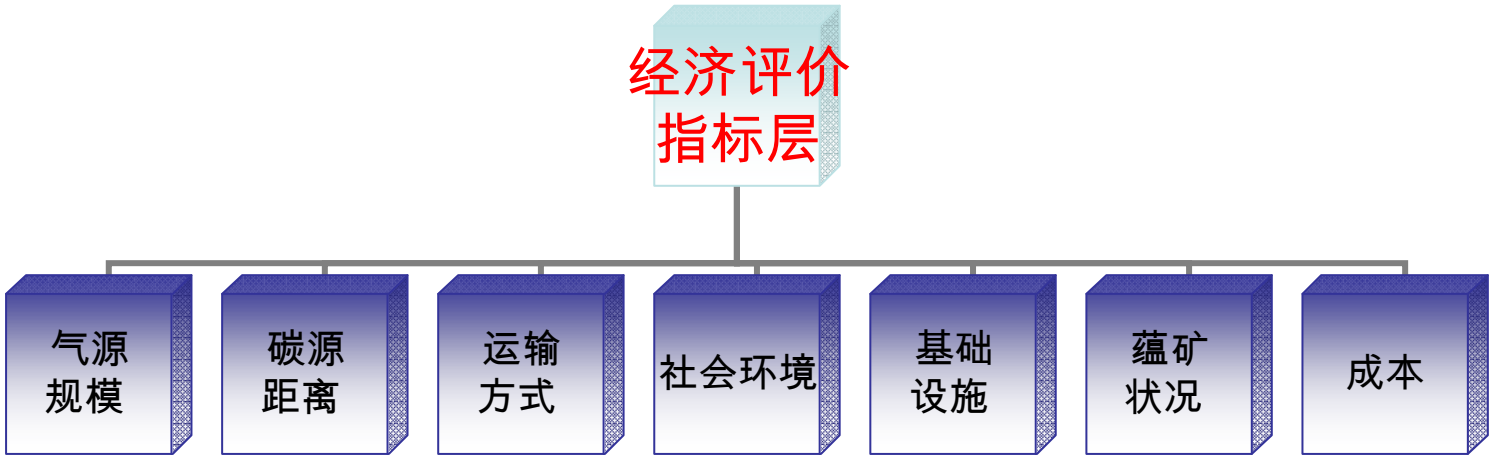
Technical Index layer	Index sublayer		Detailed indexes
	reservoir	Reservoir macro development characteristics	depth
			sand to shale ratio
		Hydrogeology condition	hydrodynamic action
			water head
			salinity
		Reservoir geothermal geology characteristics	land surface temperature
			geothermal gradient
			earth thermal current value
		Reservoir physical parameters	porosity
			permeability
			heterogeneity
		Reservoir storage prospect	effective storage amount

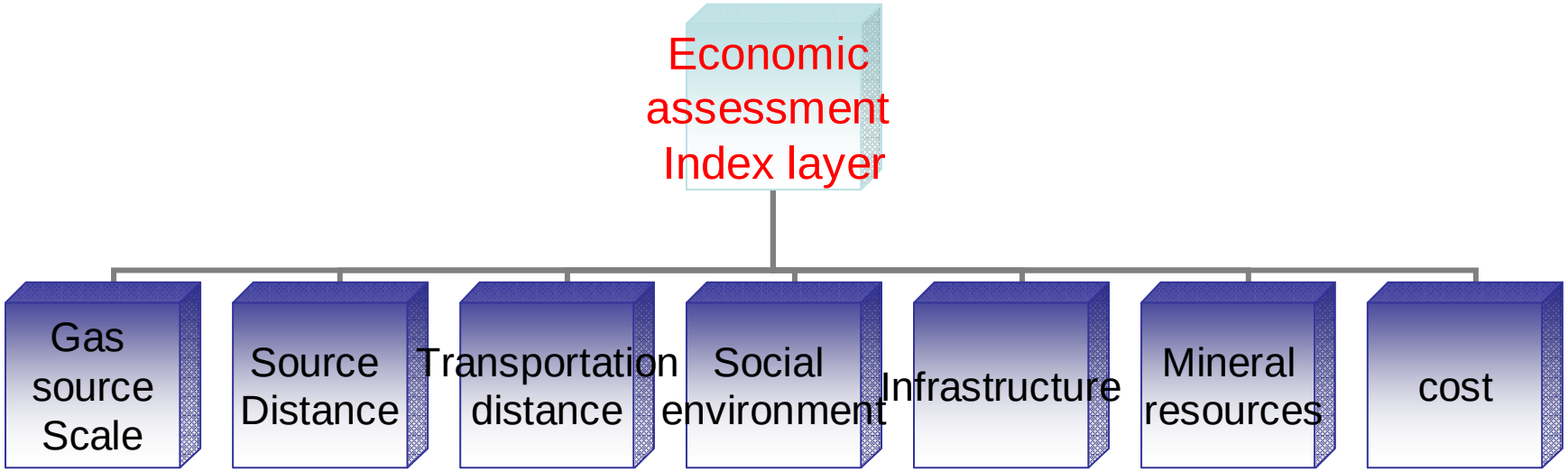

盖层适宜性评价指标
安全性评价指标层
地壳稳定性评价指标
可能的泄露通道

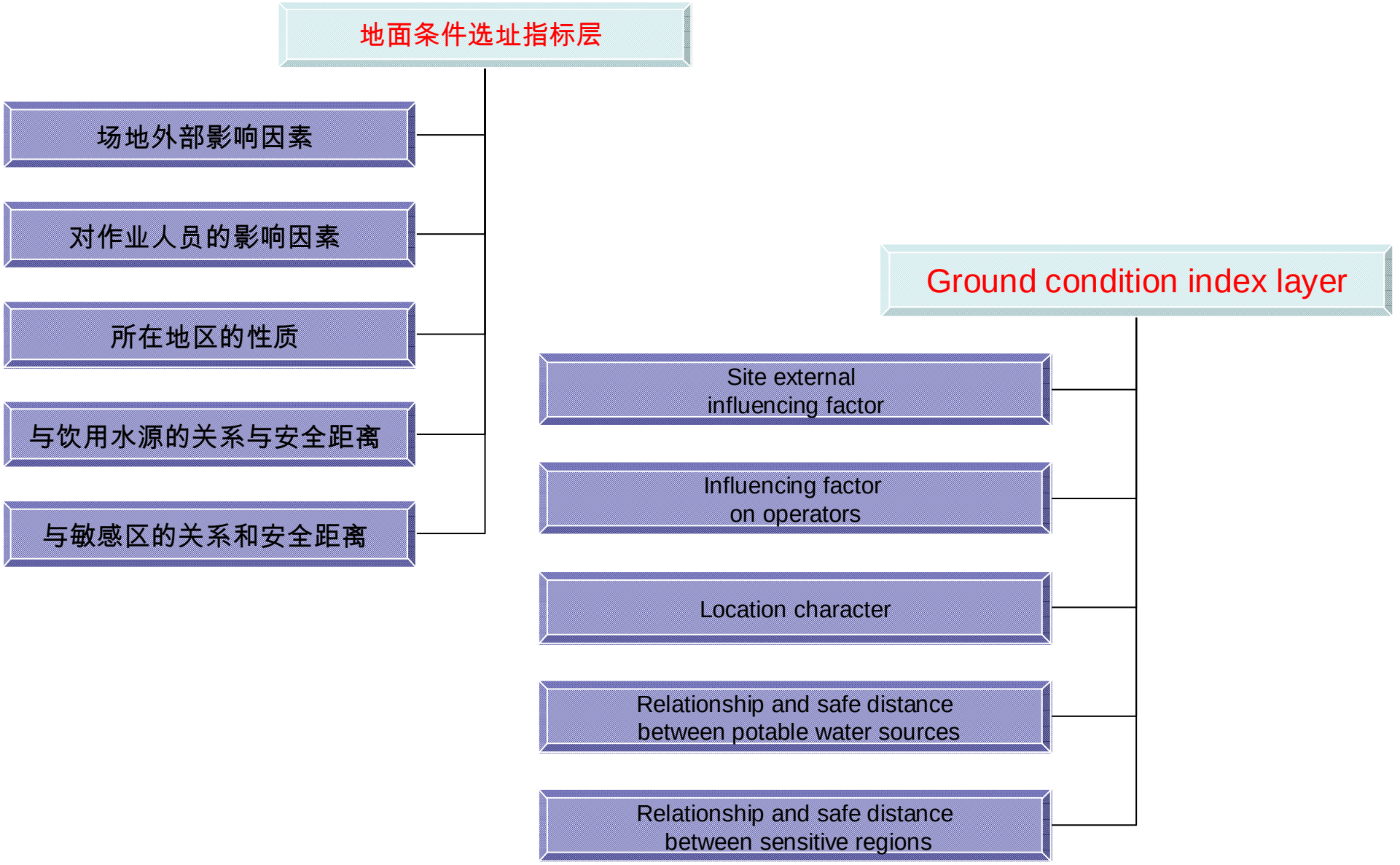

Cap rock suitability evaluation indexes
Safety evaluation index layer
Crustal stability evaluation indexes
Potential leakage channels

指标层	指标亚层		具体指标	排序标准		
				好	一般	差
安全性评价指标层	盖层适宜性评价指标亚层	盖层宏观特征评价指标	盖层的岩性	蒸发岩类	泥质岩类	页岩和致密灰岩
			盖层单层厚度（m）	> 20	10 ~ 20	< 10
			盖层累计厚度（m）	> 300	150 ~ 300	< 150
			盖层分布连续性	分布连续性，具区域性	分布基本连续	分布不连续，局限
		盖层微观封闭能力评价指标	盖层封气指数Hg（m）	> 200	100 ~ 200	< 100
		缓冲层条件评价指标	主力盖层之上的次要盖层数量	多套	一套	无
	可能的泄露通道评价指标亚层	断裂通道评价指标	断裂和裂缝发育情况	有限的裂缝，有限的断层	裂缝发育中等，发育断层中等	大裂缝，大断层
		人为通道评价指标	场地100km^{2}范围内是否有钻井及废弃井	无	有，但均做了封固处理	多，且未封固
	地壳稳定性评价指标亚层	地壳稳定性评价指标	地震动峰值加速度（g）	< 0.10g	0.10 ~ 0.15g	> 0.30g
			场地地震安全性	安全	中等	危险
			场地25km半径范围内是否有活动断层	无	—	有

Index layer	Index sublayer		Detailed indexes
Safety Index layer	caprock	macro characteristics	lithology
			single thickness
			total thickness
			distribution
		micro sealing ability	gas sealing index
		buffer layer	small caprock number
	potential leakage channels	fault	fault and crack developmental condition
		artificial leakage channel	abandoned well
	crustal stability	Crustal stability	ground motion peak acceleration
			seismic safety
			active fault


经济评价
指标层
气源
规模
碳源
距离
运输
方式
社会环境
基础
设施
蕴矿
状况
成本


Economic
assessment
Index layer
Gas
source
Scale
Source
Distance
Transportation
distance
Social
environment
Infrastructure
Mineral
resources
cost


地面条件选址指标层
场地外部影响因素
对作业人员的影响因素
所在地区的性质
与饮用水源的关系与安全距离
与敏感区的关系和安全距离
Ground condition index layer
Site external influencing factor
Influencing factor on operators
Location character
Relationship and safe distance between potable water sources
Relationship and safe distance between sensitive regions

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Thank you

for your attention!