PS Seismic Characteristics of Large-Scale Sand Injectites in Baiyun Sag, Pear River Mouth Basin, South China Sea*

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Abstract

Three-dimensional seismic data suggest the presence of six large-scale mounded structures at approximately 250m above the 18.5Ma sequence boundary surface of Neogene Baiyun sag, Pearl River Mouth Basin, South China Sea. These structures are most distinctive for their asymmetric mounded shape in cross section and irregular oval shape in plan view. They have bases raging from 826 to 3542m in diameters, with the maximum height of 403m and the largest volume of approximately 0.53km^3. The mounded structures have similar seismic reflection attributes as the sand injectites discovered at Norwegian North Sea and other places around the world. The top and base of these mounds mainly respond to continuous, medium- to high-amplitude, positive and negative reflection events; the cores of mounds are dominated by incoherent and chaotic reflections that are greatly different from the parallel sheet-like reflections of the surrounding strata. The mounded structures are interpreted as sand injectites that were generated by soft sediments deformation within Neogene Baiyun sag. The mounded structures can be classified as five types of sand injectite by their seismic reflection, which are: 1) wing-like, 2) conical, 3) mounded, 4) crestal, and 5) sheet-like. Wing-like injectites extend and tilt like wings towards outside along the edge of parent sandstones bodies. Conical injectites are characterized by cone-shape sand bodies opening upwardly, and showing V-shape amplitude anomalies on the seismic profile. Mounded injectites are those dome structures formed by liquefied sand injecting upward, and seen as irregular ellipse in plan view. Crestal injectites consist of complicated networks of intrusion formed by unconsolidated sand interfingering. Sheet-like injectites are concordant intrusion sill, with height ranging from tens to hundreds of meters. Wing-like and crestal sand injectites are distributed as isolated structures. Conical and mounded sand injectites are characterized by linearly distributing large structure groups, which extend along a preferable direction. Subsurface sand injectites are potential reservoirs with high porosity and permeability, and are usually confined by low-permeability mudstone and shale, making them good lithologic trap with advantageous reservoir-seal combination conditions. Many commercial reservoirs of sandstone intrusions have been discovered, indicating that sandstone intrusions have favorable prospects in hydrocarbon exploration.

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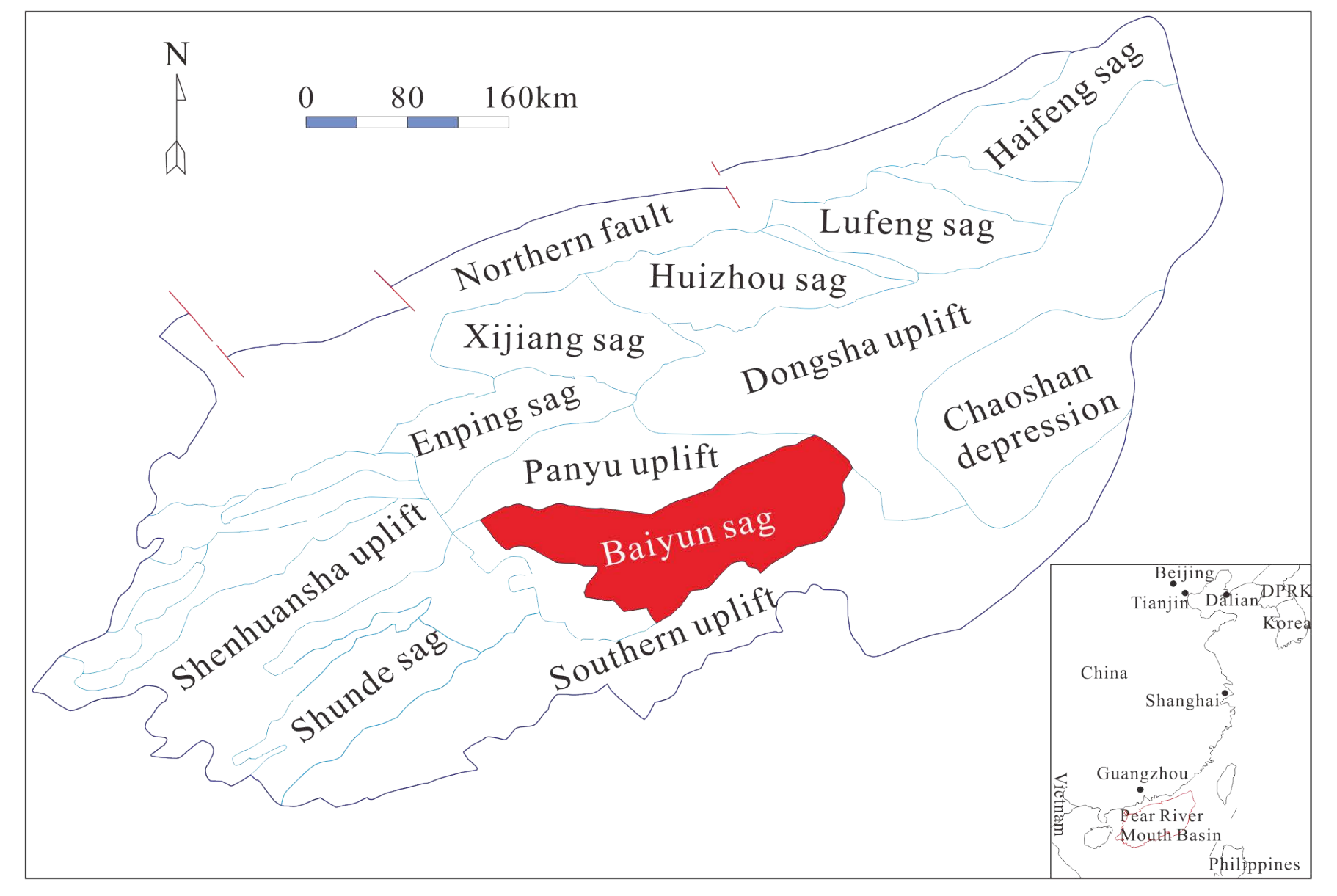
Abstract

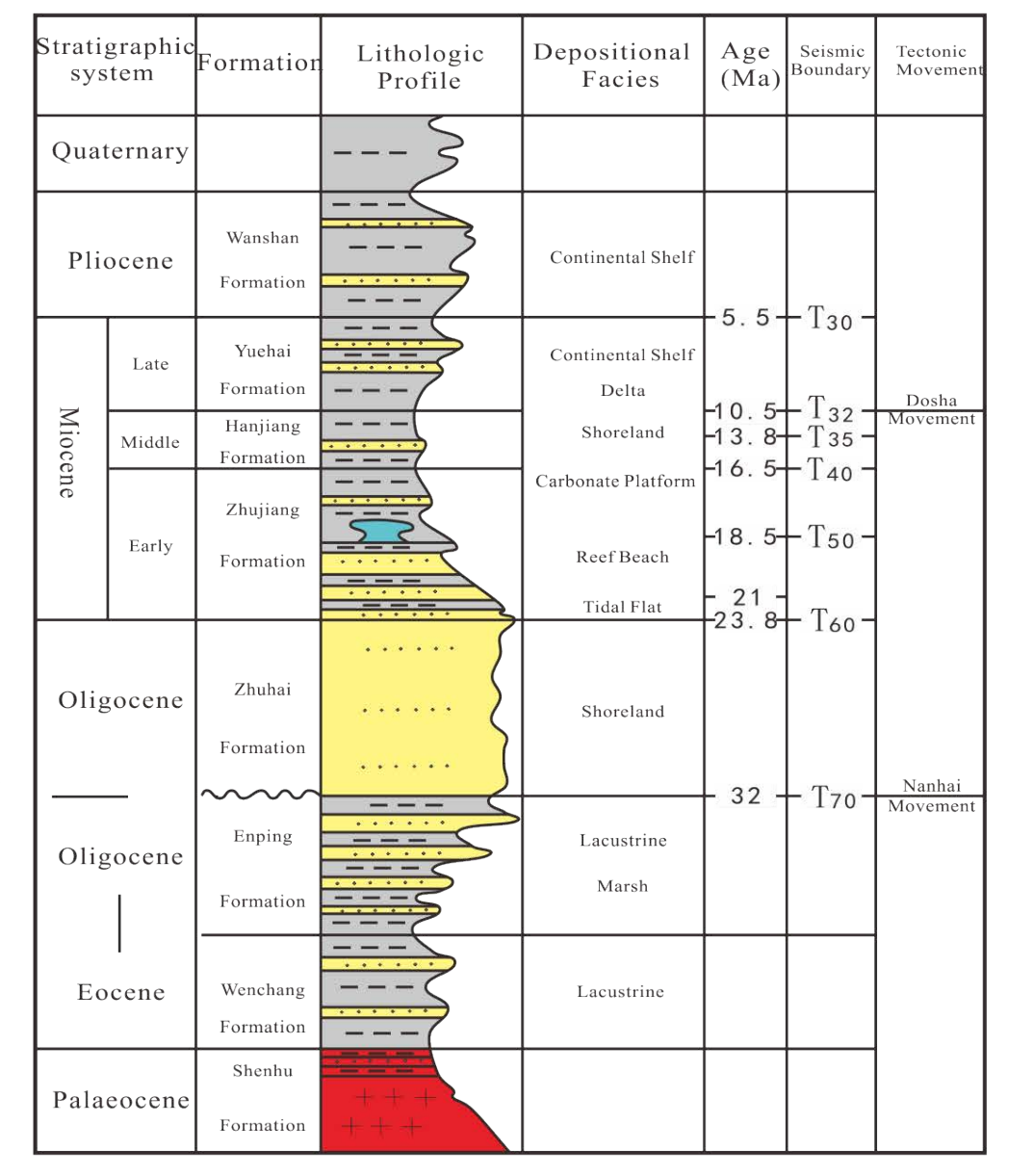
Three-dimensional seismic data suggest the presence of six large-scale mounded structures at approximately 250m above the 18.5Ma sequence boundary surface of Neogene Baiyun sag, Pearl River Mouth Basin, South China Sea. These structures are most distinctive for their asymmetric mounded shape in cross section and irregular oval shape in plan view. They have bases raging from 826 to 3542m in diameters, with the maximum height of 403m and the largest volume of approximately 0.53km3. The mounded structures have similar seismic reflection attributes as the sand injectites discovered at Nowegian North Sea and other places around the world. The top and base of these mounds mainly respond to continuous, medium- to high-amplitude, positive and negative reflection events; the cores of mounds are dominated by incoherent and chaotic reflections that are greatly different from the parallel sheet-like reflections of the surrounding strata. The mounded structures are interpreted as sand injectites that were generated by soft sediments deformation within Neogene Baiyun sag.

The mounded structures can be classified as five types of sand injectite by their seismic reflection, which are: 1) wing-like;2) conical;3) mounded;4) crestal, and 5) sheet-like. Wing-like injectites extend and tilt like wings towards outside along the edge of parent sandstones bodies. Conical injectites are characterized by cone-shape sand bodies opening upwardly, and showing V-shape amplitude anomalies on the seismic profile. Mounded injectites are those dome structures formed by liquefied sand injecting upward, and seen as irregular ellipse in plan view. Crestal injectites consist of complicated networks of intrusion formed by unconsolidated sand interfingering. Sheet-like injectites are concordant intrusion sill, with height ranging from tens to hundreds of meters. Wing-like and crestal sand injectites are distributed as isolated structures. Conical and mounded sand injectites are characterized by linearly distributing large structure groups, which extend along a preferable direction. Subsurface sand injectites are potential reservoirs with high porosity and permeability, and are usually confined by low-permeability mudstone and shale, making them good lithologic trap with advantageous reservoir-seal combination conditions. Many commercial reservoirs of sandstone intrusions have been discovered, indicating that sandstone intrusions have favorable prospects in hydrocarbon exploration.

1 Geological Setting

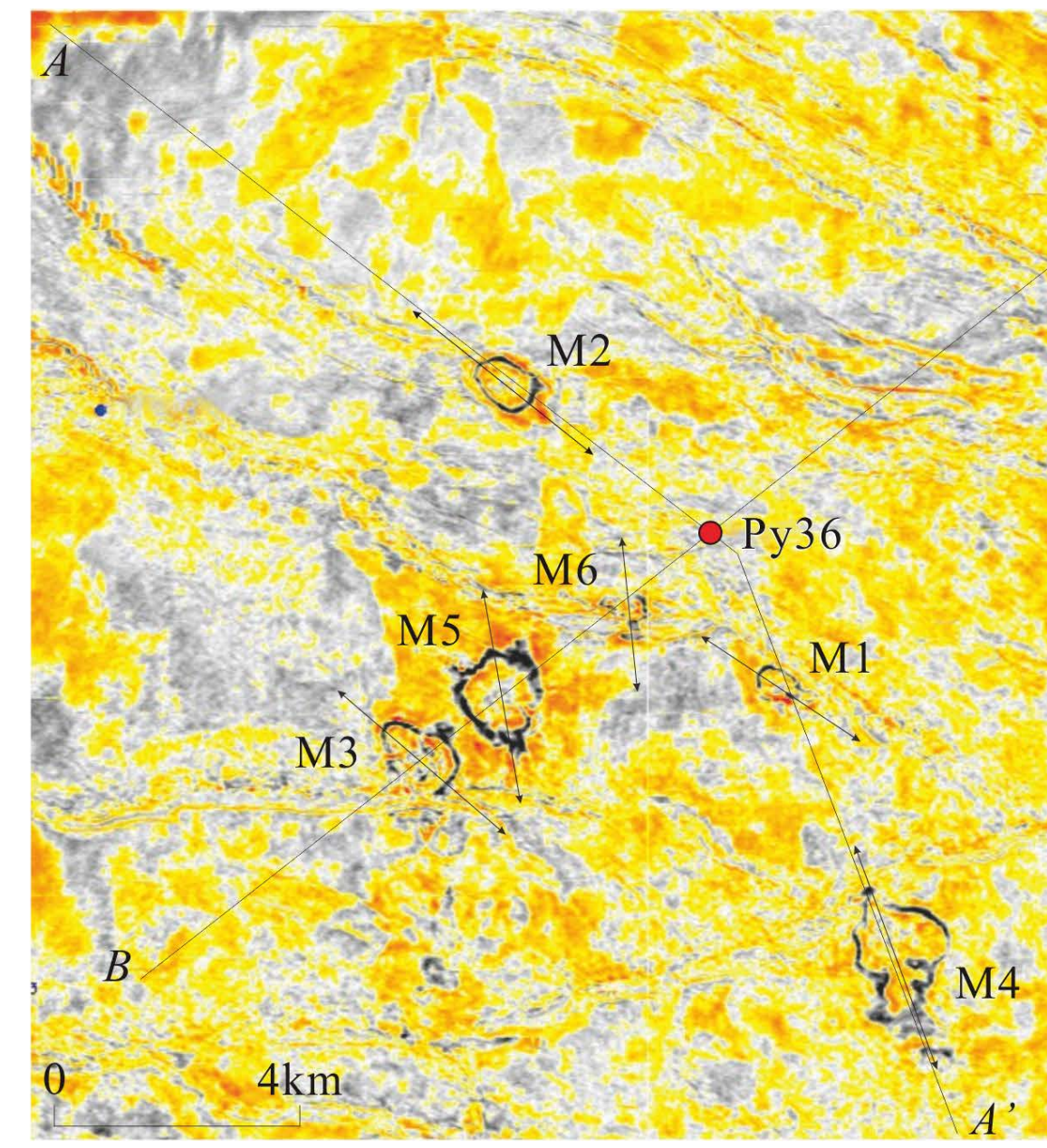
Pearl River Mouth Basin, as an extension of the South China mainland, is located in the north of the South China Sea. It was a quasi-passive continental margin basin formed in a tension stress field. This basin locates in the junction of Eurasian plate, Pacific plate and Indo Australian plate. The structural deformation in plane was characterized by belts in S-N and blocks in E-W. SSD were developed in the special geologic background and evolution process.

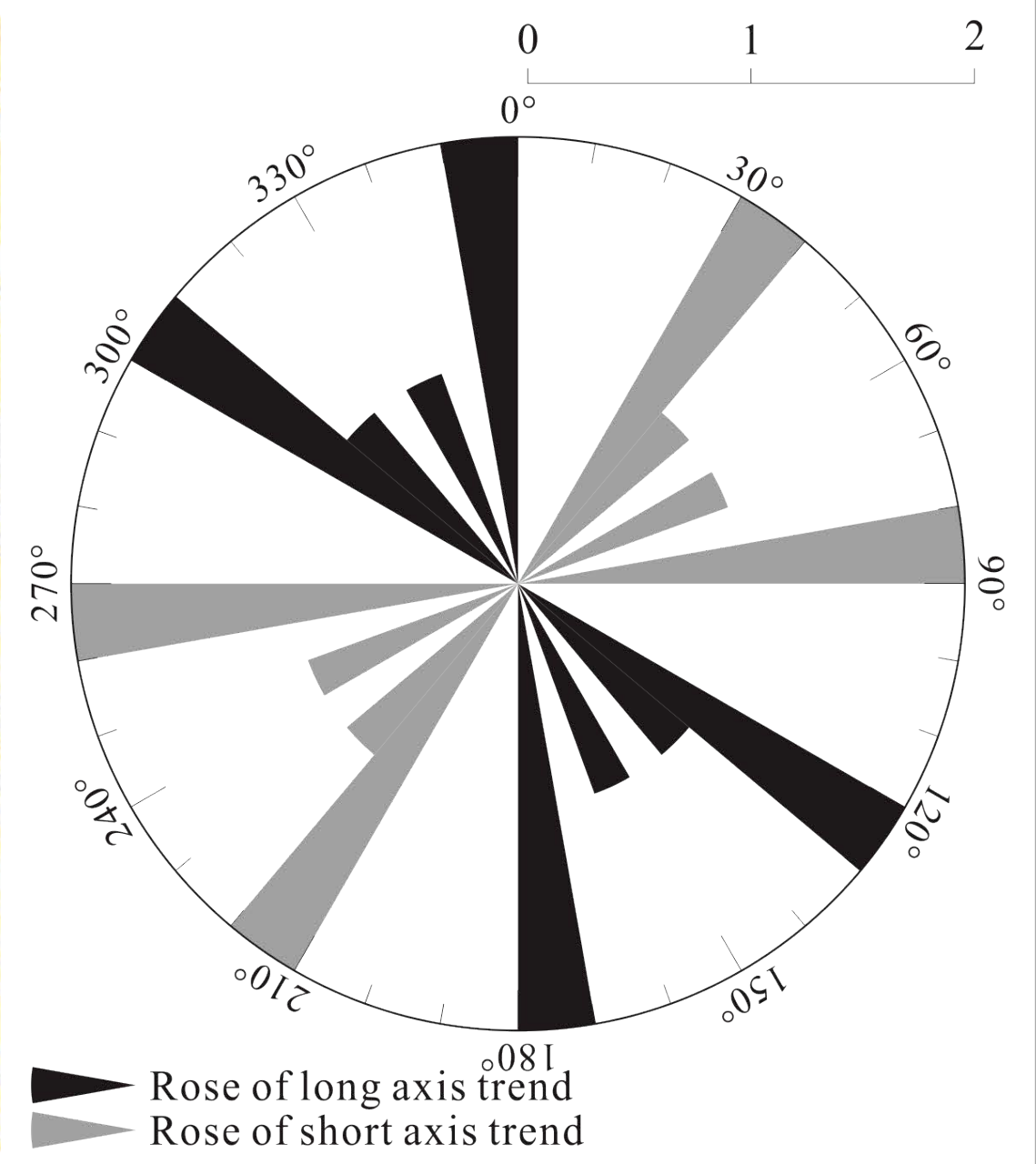




2 Planimetric distribution characteristic and seismic reflection characteristics of mounded structures in the Baiyun sag in Pearl River Mouth Basin

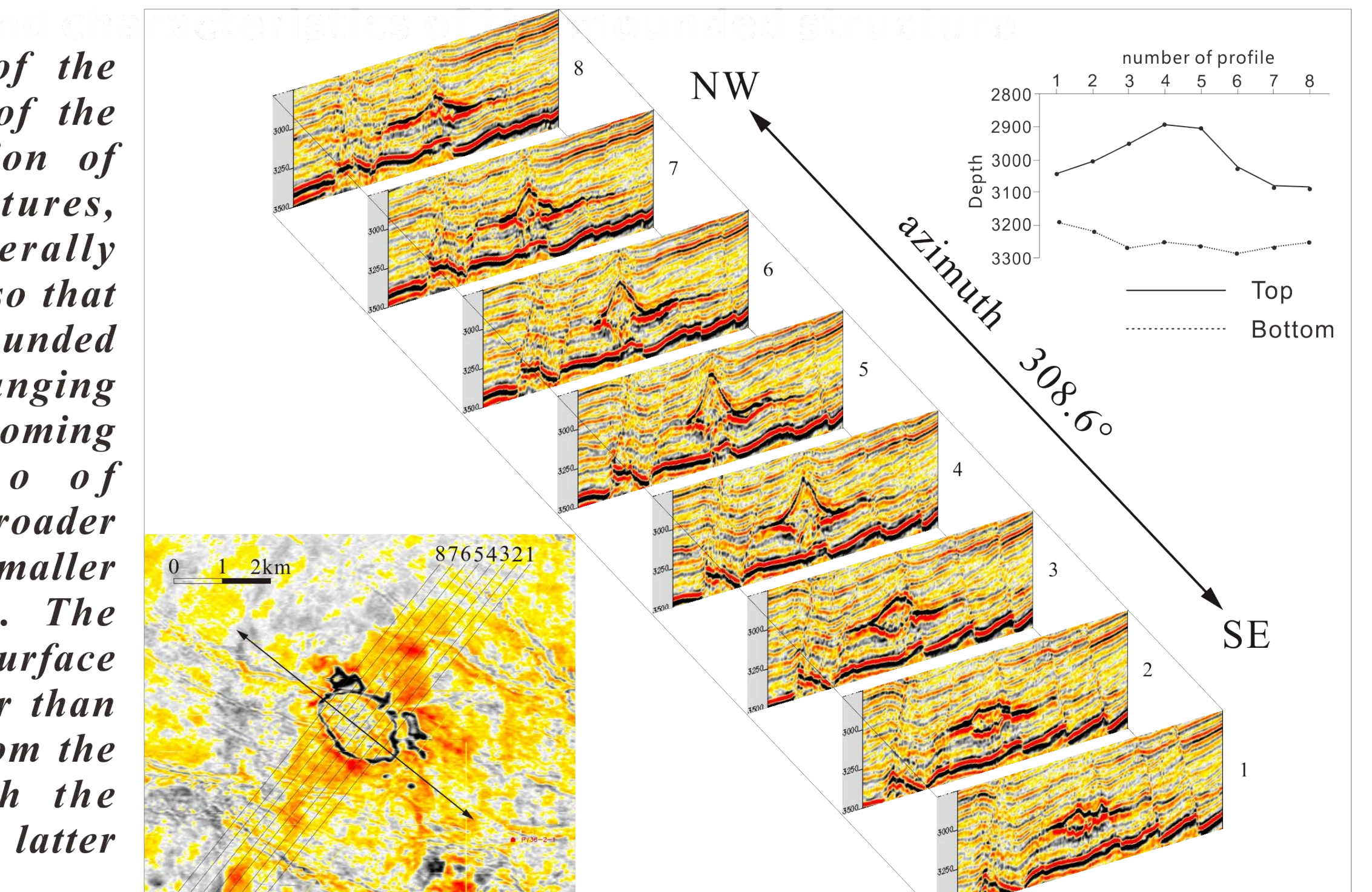
The mounded structures were irregular ellipticity on plane and extended directively on horizon while the long axis was perpendicular to the minor axis. Six mounded structures were named from M1 to M6 divided into two group. The similar strike of M1, M2, M3 were NWW 307.6° and those of M4, M5, M6 were NNW 348.1°.

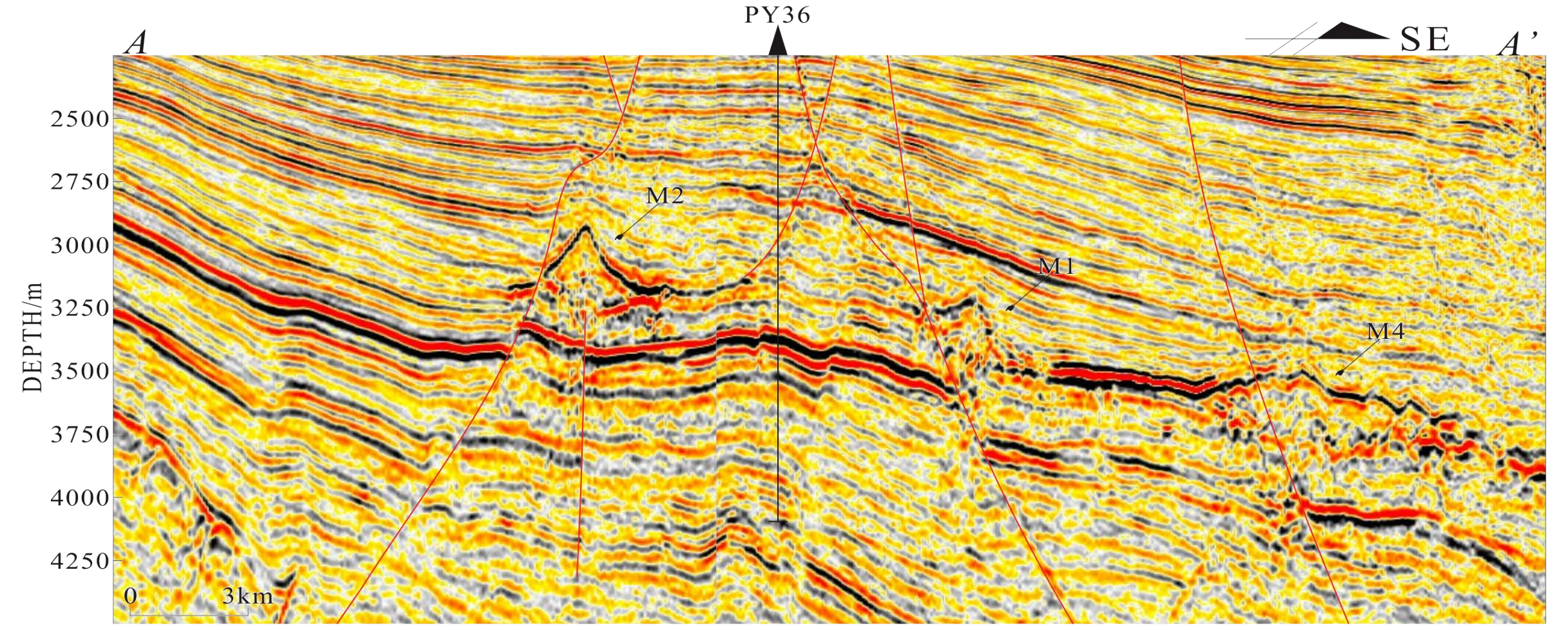


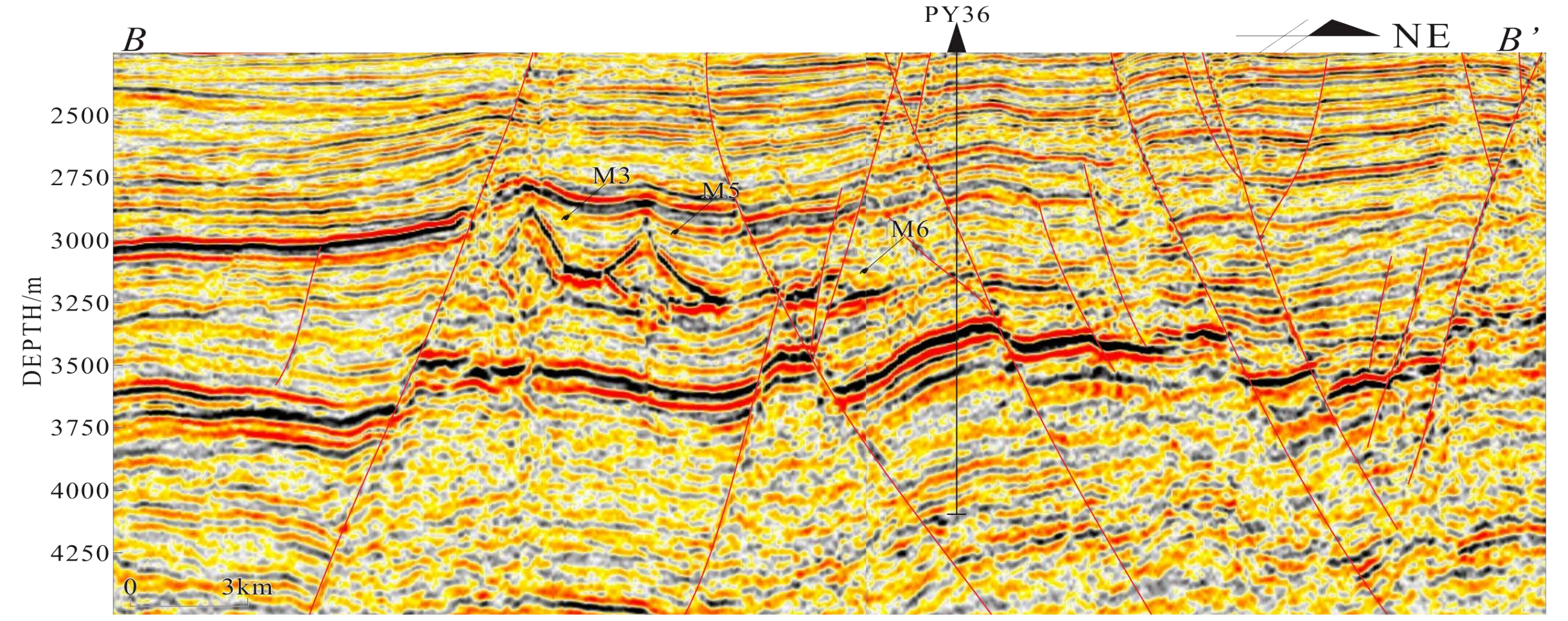


Rose of long axis trend
Rose of short axis trend

The highest point of the structures, a place of the most intense intrusion of the mounded structures, was collapsing laterally along the long axis, so that the shape of the mounded structures were changing subsequently and becoming larger the ratio of crest/flank width, broader fastigiate crest and smaller flank dip gradually. The fluctuation of top surface was obviously greater than bottom along axis from the core to flank, with the former 190m and the latter 92m.







Among the mounded structures developing near faults, M1, M2, M3, M5 presented similar asymmetrical mound with fastigiate crest, and M4 was the largest while its crest were flat.

Moundy structures of overlying strata was sheeted - sheet draped. It had a generally parallel-subparallel reflection structure, reflecting weaker than internal reflection in mound.

Measured in 3-D seismic data of depth domain, the 3-D geometry parameters of the mounded structure, such as height, the long / short extension direction, diameter, area and volume, were different from each other. Clear boundary between mounded structure and underlying strata were generally conformable, while Overlying strata with drape deposit was onlap to the top surface of mounded structure. There was tubular passageway below the moundy structure with chaotic seismic

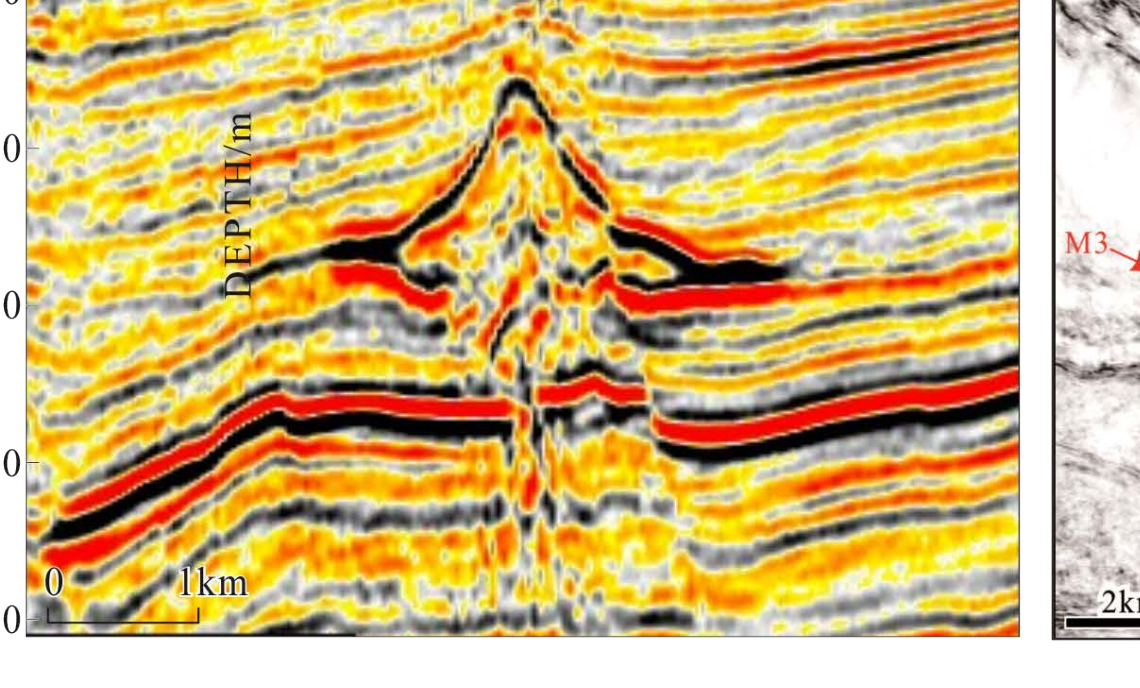
Shape parameters and characteristics of mound

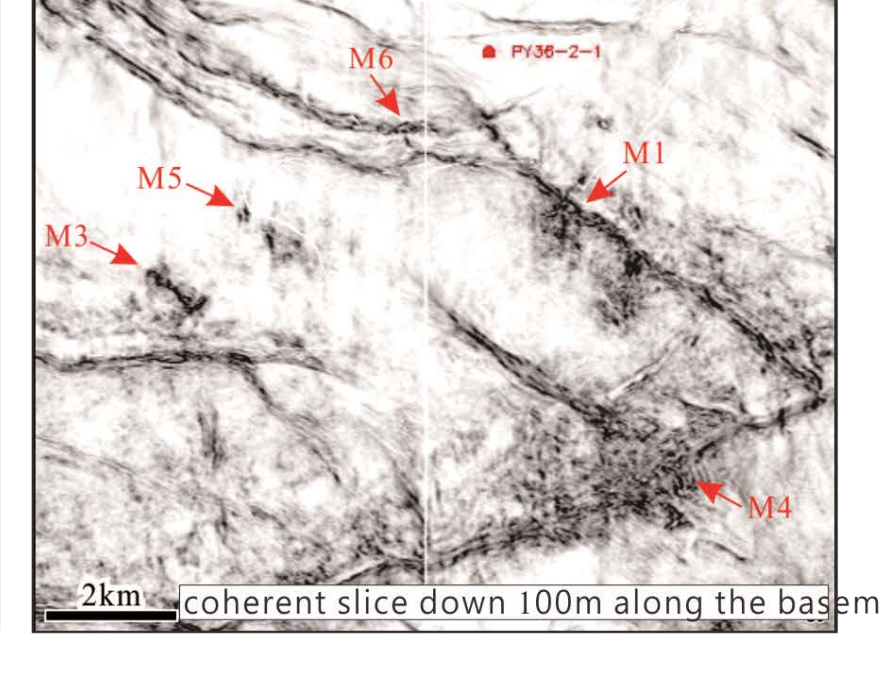
samples	Centre height in core /m			Extension direction/°		Base diameter /m		Bed area /km²	Volume /km³	Contact with surrounding rock		Intrude channel	Related to the nearby fault
	top	bottom	fall	Long axis	Short axis	Long axis	Short axis			overlying layer	underlayer		
M1	3105	3438	333	303.5	33.5	825.5	622.9	0.39	0.04	drape	conformity	Y	Channel is cut-off by fault
M2	2894	3258	364	308.6	38.6	1861.2	1344.6	1.69	0.21	drape	conformity	Y	Flank is cut-off by fault
M3	2813	3183	370	310.6	40.6	1632.3	1154.5	1.28	0.16	drape	conformity	Y	About 1.5km to fault
M4	3465	3798	333	339.8	69.8	3542.0	2130.9	4.79	0.53	drape	conformity	Y	Flank and channel are cut-off by fault
M5	2880	3283	403	350.0	80.0	1878.7	1485.0	1.90	0.26	drape	conformity	Y	Clamping in fault entirely
M6	3072	3295	223	354.4	84.4	1126.7	485.3	0.95	0.07	drape	conformity	Y	cut-off by fault entirely
ave	3037	3375	338	327.8	57.8	1811.1	1203.9	1.83	0.21	\	\	\	\

3 Five types of sand injectite by their seismic reflection

Seismic reflection external geometric configuration of subsurface sandstone intrusion can be classified as five main forms: winglike, conical, mounded, crestal and sheet, that can be subdivided into ten subtypes according to the morphologic characteristic, formation mechanism, compound mode and the interaction between faults and intrusion. Sandstone intrusion is characterized by height from ten of meters to hundreds of meters.

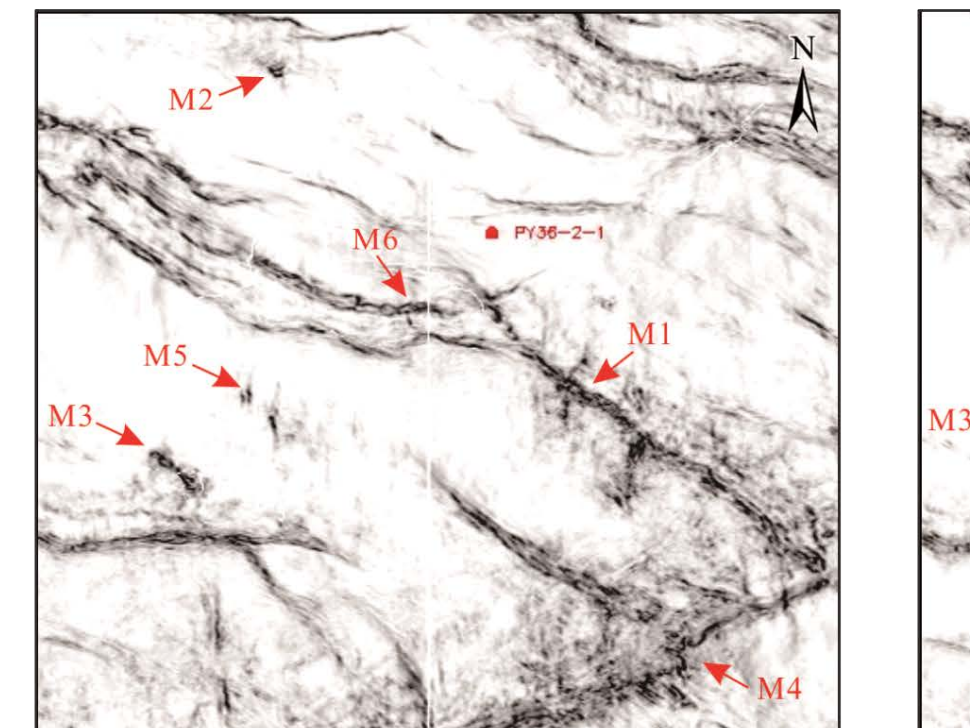
Types of sand injections		Geometry	Height /m	Extended lenghth /km	Dip angel /°	Morphological feature	Parent sandstone types
Types	Subtypes						
Wing-like injectites	W1 type	Alary	100-200	0.24-0.8	5-25	Clastic dike injected inclindly upward to the overlying strata and pinched out gradually	Channel infilled sandstone, turbidite sandatone
	W2 type	Alary	200-400	0.9-1.5	20	Clastic dike injected inclindly upward to the overlying strata and turned to be horizontal subordinate sill in the distal end	Channel infilled sandstone
	W3 type	Alary	100	0.5	20	Clastic dike injected inclindly upward to the overlying strata and turned to be horizontal subordinate sill in the distal end then continued injecting upward until to be a new sill	turbidite sandatone
Conical injectites	C1 type	Cone-shaped	200-400	0.5-1	25-40	V-shape injected dike in profile, relative Symmetric configuration, vertical passageway can be seen in the bottom	turbidite sandatone
	C2 type	Complex cone	300	1	30.5-45	W-shape injected dike in profile, vertical passageway were linked together with the two hinge zone in the bottom	turbidite sandatone, submarine fan
	C3 type	Cone-shaped	100-200	0.5-1	5.5-44	V-shape injected dike get across to fault in profile	
	C4 type	Cone-shaped	150-250	0.35-0.75	42-68	One branch of the clastic dike injected along the fractured surface	
	C5 type	Cone-shaped	140-240	0.4-0.85	25-52	One branch of the clastic dike injected along the fractured surface and then turned to be horizontal sill in the distal end	
Mounded injectites	M1 type	Mounded	30-80	0.4-0.8	5-20	Broad and gentle slopping mounded structure whose bottom was flat and no break	Submarine valley infilled sandstone
	M2 type	Mounded	200-400	1-4	10-40	Gently steep slopping mounded structure whose bottom was linked with the vertical passageway, bottom of core was breaked by fault	Submarine valley infilled sandstone, Shelf-edge delta
Crestal injectites	Coronal	Coronal	100-200	\	\	complex intrusion network due to the crisscross of injective dike	turbidite sandatone, submarine fan
Sheet-like injectites	Sheet	Sheet	130	3	\	Sheet sill along the strata, vertical passageway can be seen in the bottom	Not available



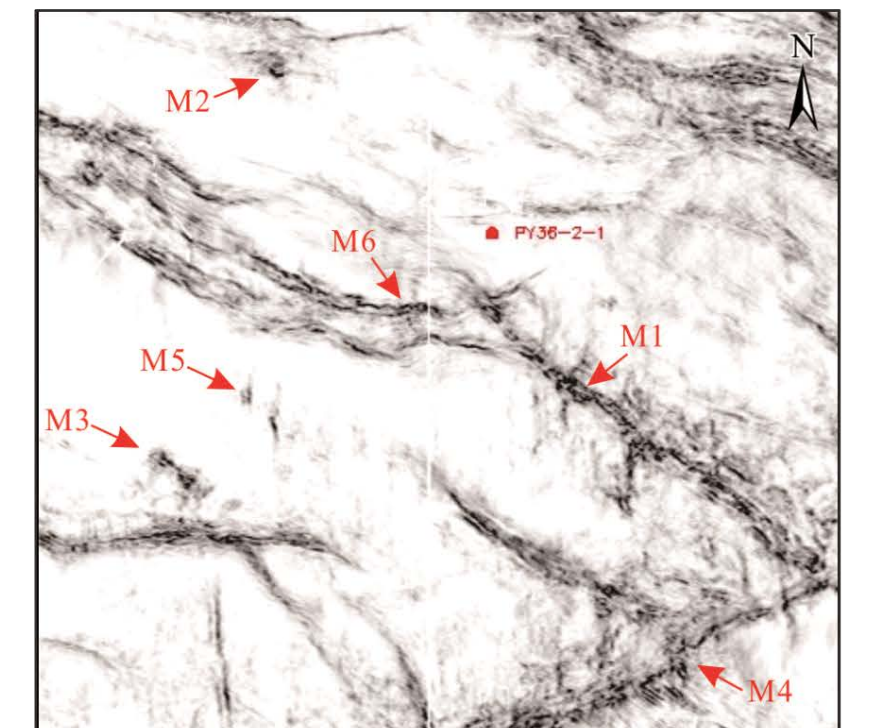


coherent slice down 100m along the basement

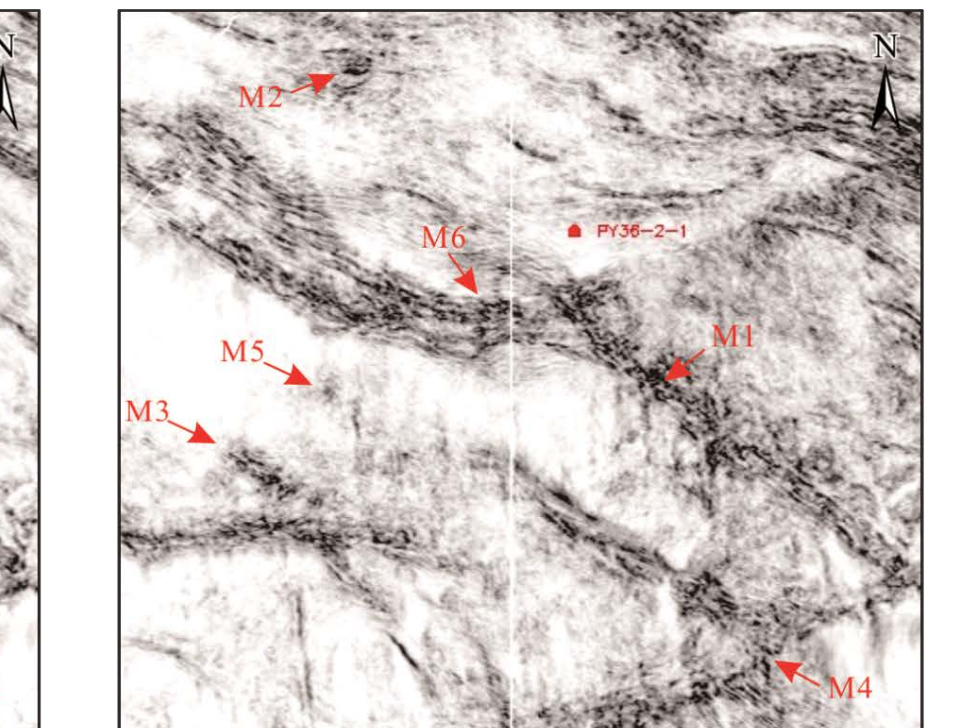
The strata underlying moundy structures showed sheet with parallel - sub parallel reflection. The seismic reflection of bottom moundy structures indicated chaotic with nearly vertical anomalous reflection zone. In a certain range it extended downward proved with random reflection morphological features.



coherent slice down 200m along the basement



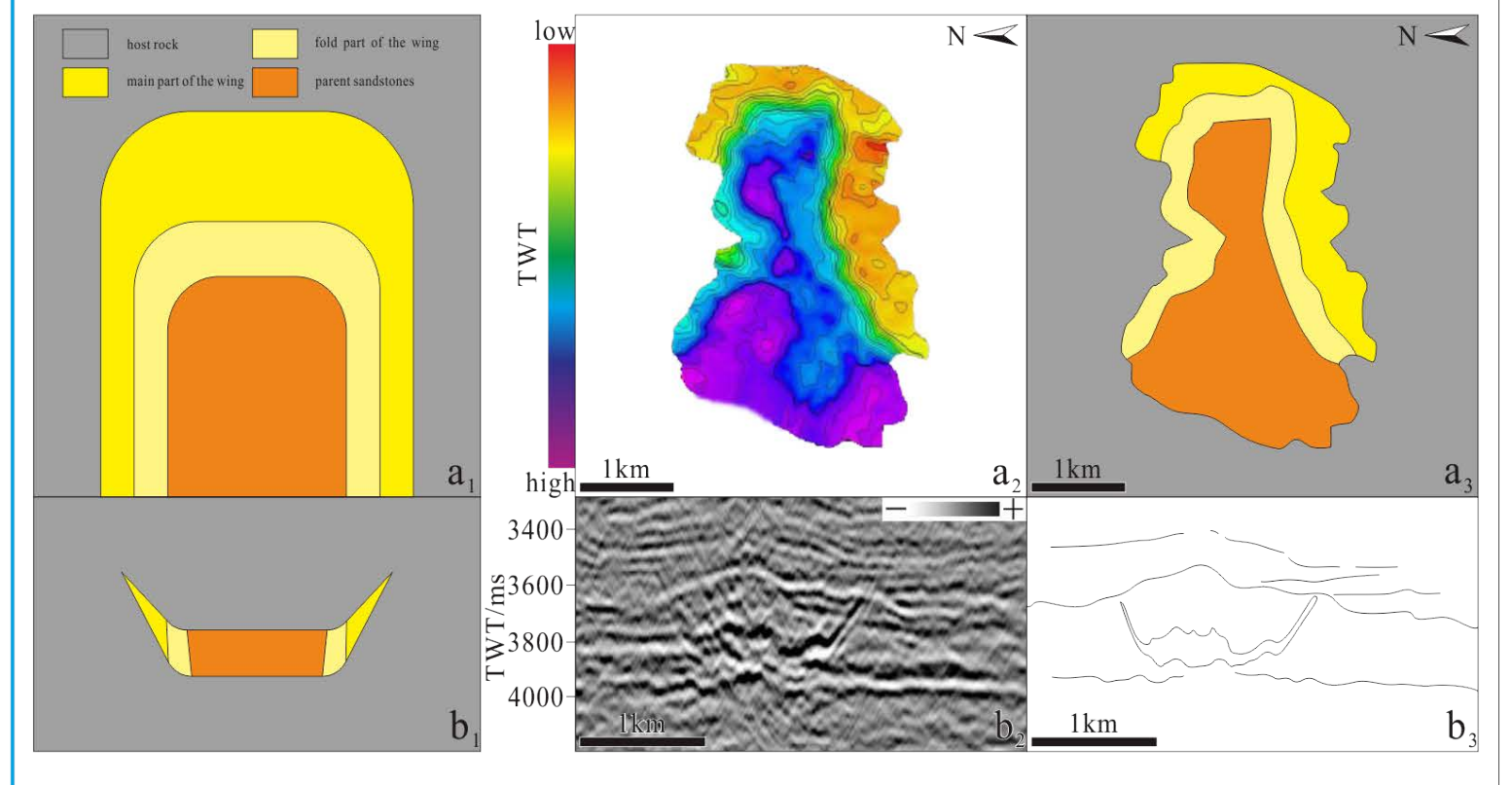
coherent slice down 300m along the basement



coherent slice down 400m along the basement

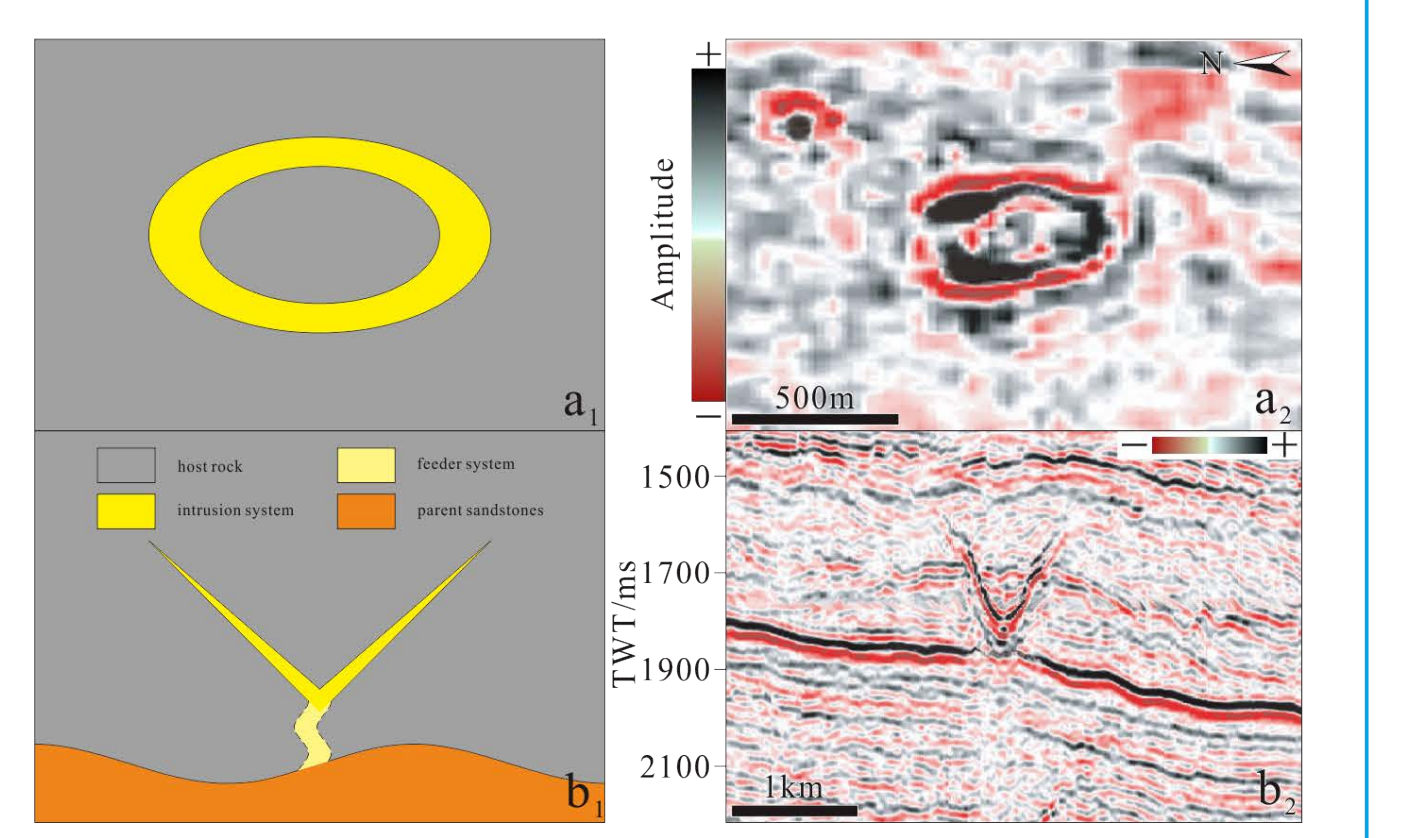
3 Five types of sand injectite by their seismic reflection (CONT)

Wing-like injectites



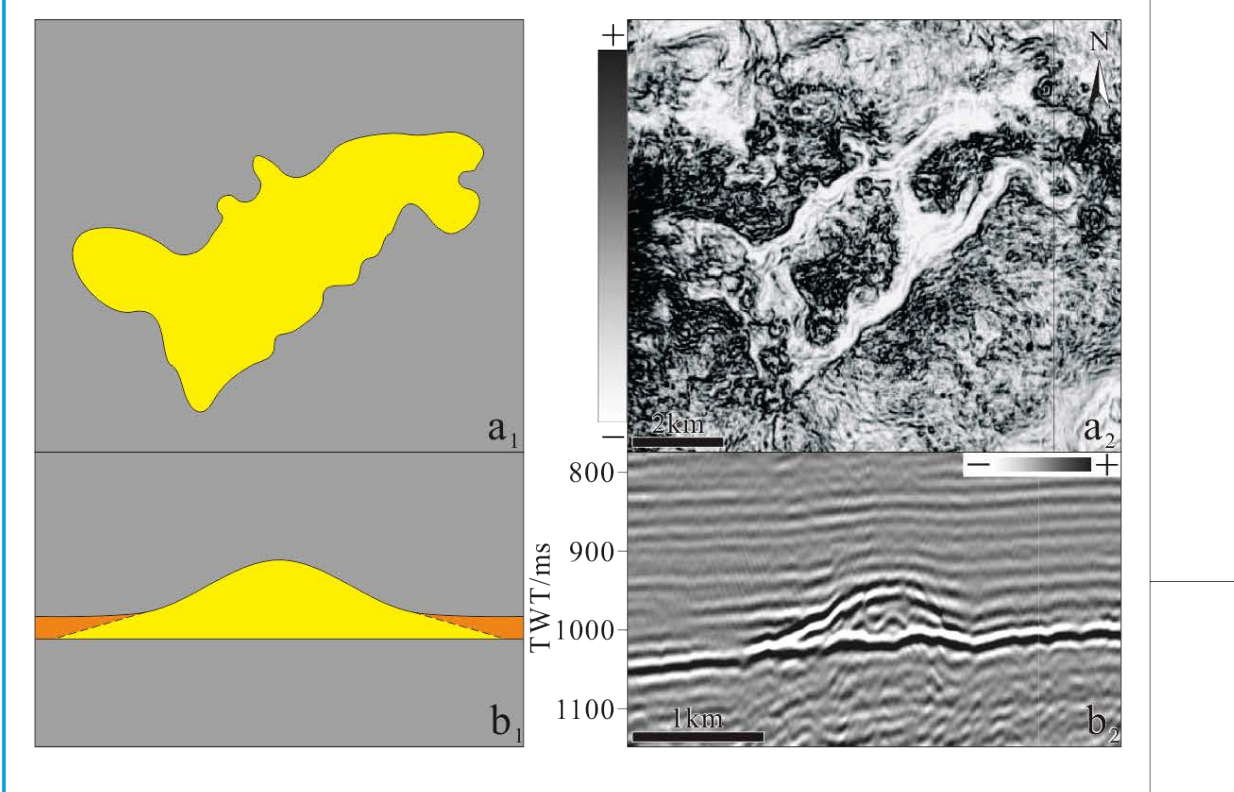
Wing-like injectites extend and tilt like wings towards outside along the edge of parent sandstones bodies.
a1-Morphologic model of horizontal section of axisymmetric regular wing-like injectite.
a2-Time structure map of top of wing-like injectite (Szarawarska et al, 2010, modification).
a3-The interpretation of b2 (Szarawarska et al, 2010, modification).
b1-Morphologic model of vertical section of axisymmetric regular wing-like injectite.
b2-Seismic reflection characteristics of vertical section of wing-like injectite (Duranti and Hurst, 2004, modification).
b3-The seismic interpretation of c2 (Duranti and Hurst, 2004, modification)

Conical injectites



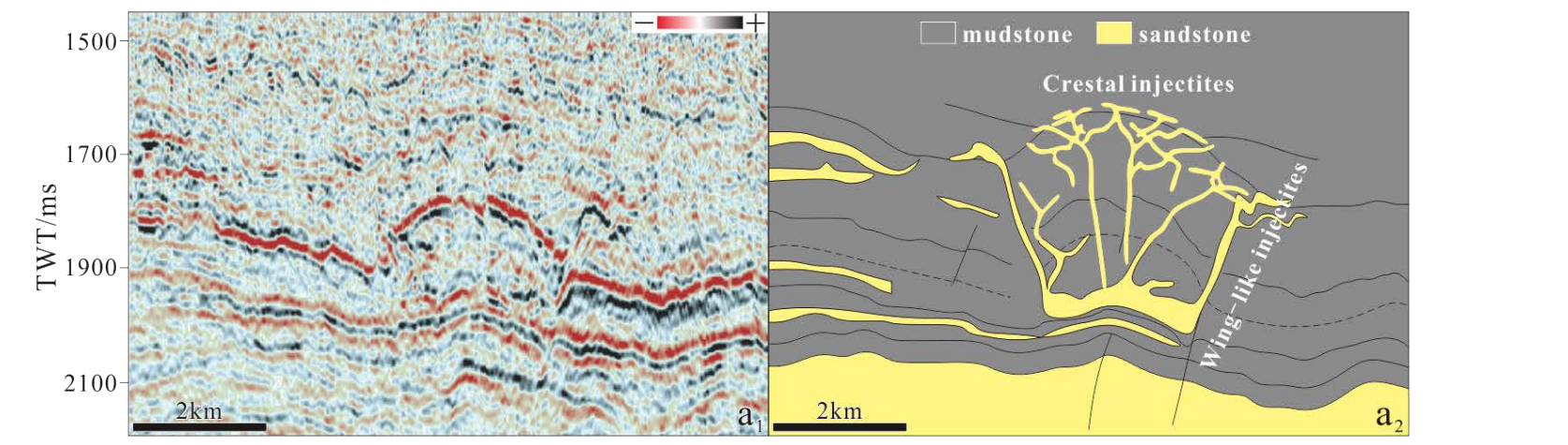
Conical injectites are characterized by cone-shape sand bodies opening upwardly, and showing V-shape amplitude anomalies on the seismic profile.
a1-Morphologic model of horizontal section of axisymmetric regular conical injectite.
a2-Amplitude slice of conical injectite (Huuse and Mickelson, 2004, modification).
b1-Morphologic model of vertical section of axisymmetric regular conical injectite.
b2-Seismic reflection characteristics of vertical section of conical injectite (Huuse and Mickelson, 2004, modification).

Mounded injectites



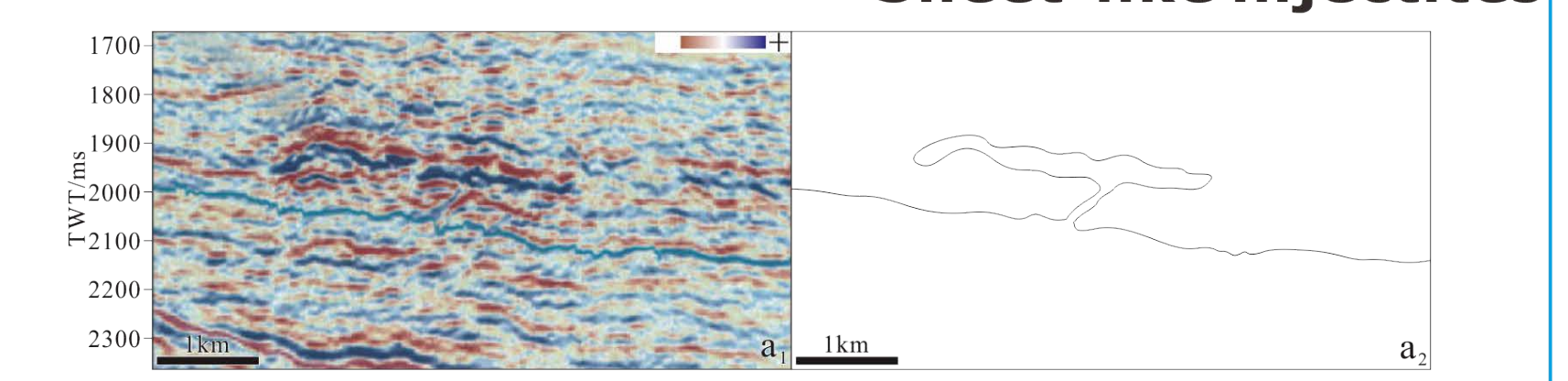
Mounded injectites are those dome structures formed by liquefied sand injecting upward, and seen as irregular ellipse in plan view.
a1-Morphologic model of horizontal section of symmetrical regular mounded injectite.
a2-Interior seismic reflection configuration of mounded sandstone intrusions in the Eastern Mediterranean (Frey-Martinez et al, 2007).
b1-Morphologic model of vertical section of symmetrical regular mounded injectite.
b1-Seismic reflection characteristics of vertical section of mounded injectite (Andresen et al, 2009).

Crestal injectites



Crestal injectites consist of complicated networks of intrusion formed by unconsolidated sand interfingering.
a1-Seismic reflection characteristics of vertical section of crestal injectite (Huuse et al, 2007, modification).
a2-The seismic interpretation of b1 (Huuse et al, 2007, modification).

Sheet-like injectites



Sheet-like injectites are concordant intrusion sill, with height ranging from tens to hundreds of meters.
a1-Seismic reflection characteristics of vertical section of sheet-like injectite (Hurst et al, 2005, 2006, modification).
a2-The seismic interpretation of c1 (Hurst et al, 2005, 2006, modification).

4 Conclusion

- † Three-dimensional seismic data suggest the presence of six large-scale mounded structures in the Baiyun sag, Pearl River Mouth Basin, South China Sea.
- † The mounded structures in Baiyun sag have similar seismic reflection characteristics as the mounded sandstone injectites reported previously in other countries.
- † Seismic reflection external geometric configuration of subsurface sandstone injectites can be classified as five main forms: wing-like, conical, mounded, crestal and sheet-like.

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