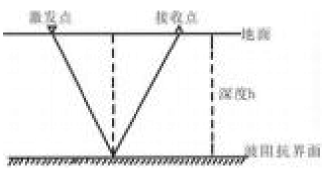
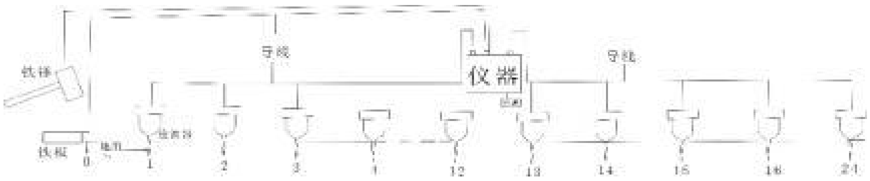
1. Combined exploration of metal ore voids using multi-source seismic reflection imaging and high-density resistivity methods

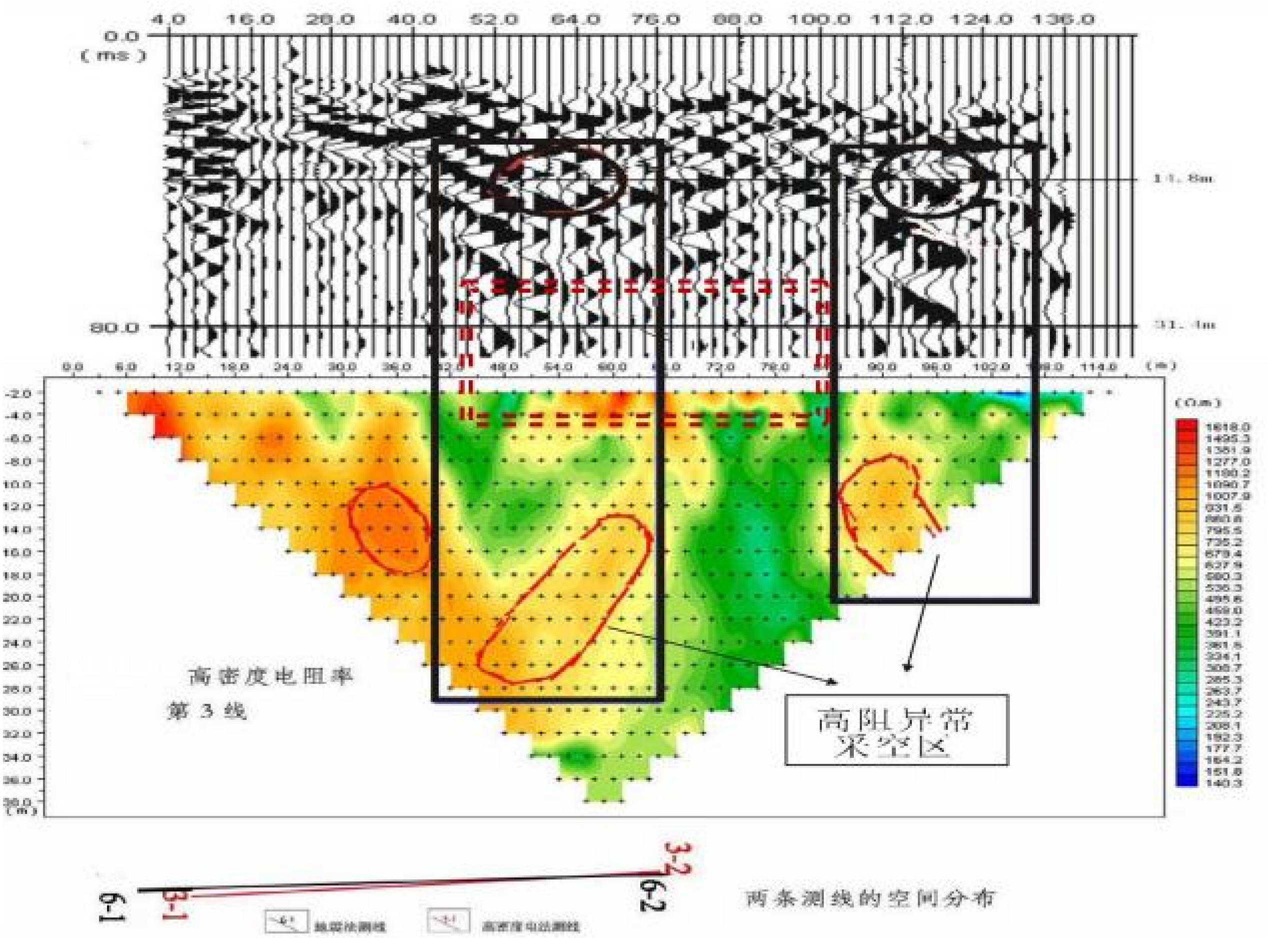
In the multi-source offset seismic reflection method, the time-distance curve equation for the reflected wave is given by $t_{反} = \frac{1}{v}\sqrt{4h^2 + x^2}$, where x is the source-receiver offset, H is the depth of the interface, and v is the P-wave velocity of the medium.



Schematic diagram of the working principle

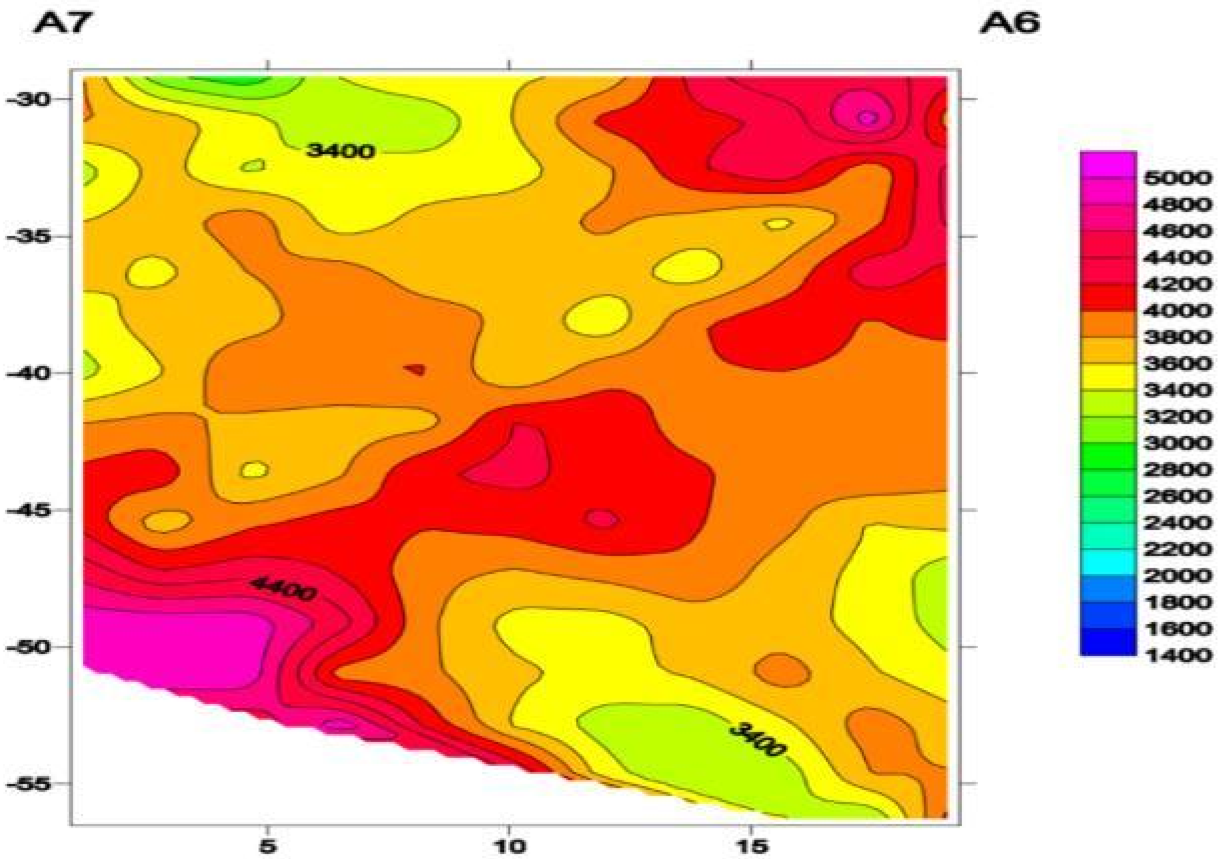


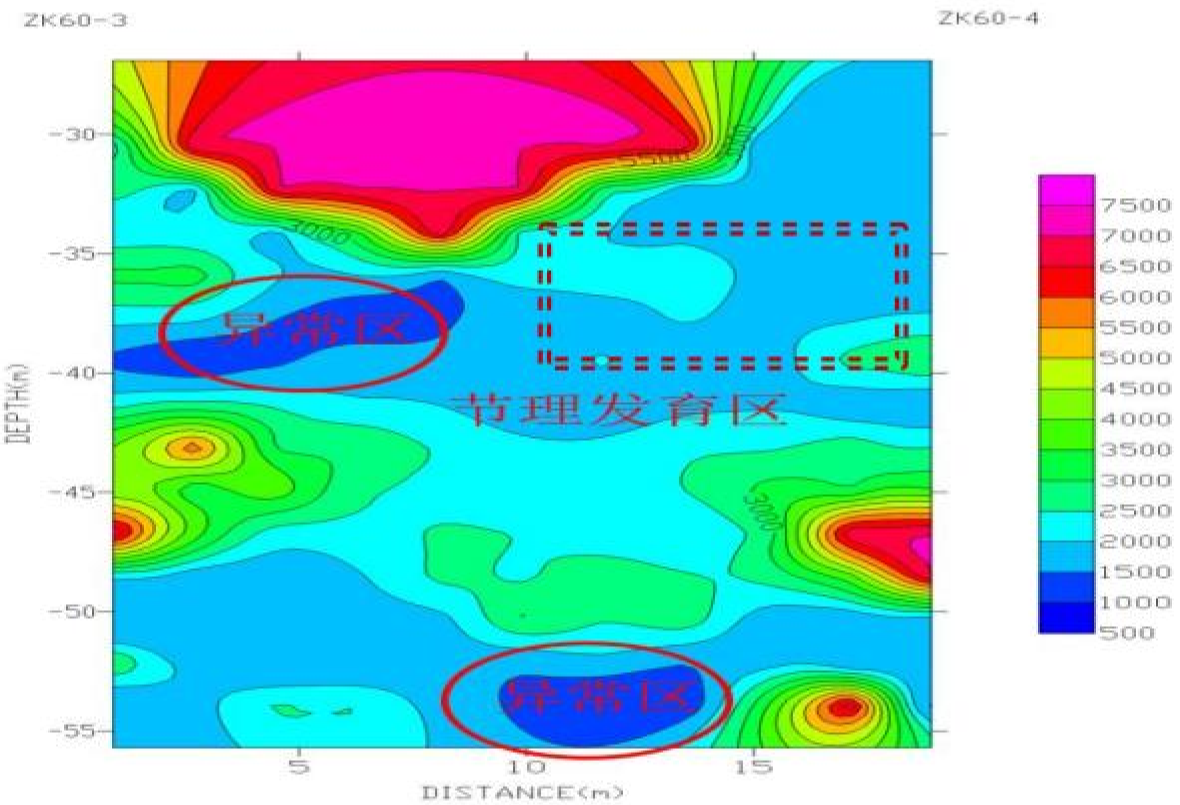
Schematic diagram of the multi-source offset seismic reflection method



At a source-receiver offset of 12m, the intensity of the seismic waves (the circled part) between 55-60m and 106-122m on the survey line increases. The features of offset and bending of the seismic wave's same-phase axis, as well as the increase in the number of seismic wave phases, match the characteristics of seismic wave propagation in void areas. The anomalies are most pronounced, indicating the optimal source-receiver offset, and it is preliminarily inferred to be a void area. By comparing, it can be seen that the results obtained from the seismic imaging method are in complete agreement with the high-resistance anomalies shown by the high-density survey line. It can be concluded that the top burial depth of the first void area is about 13m, and the second void area is about 11m deep. This shows that the multi-source offset seismic reflection method is effective for detecting void areas.

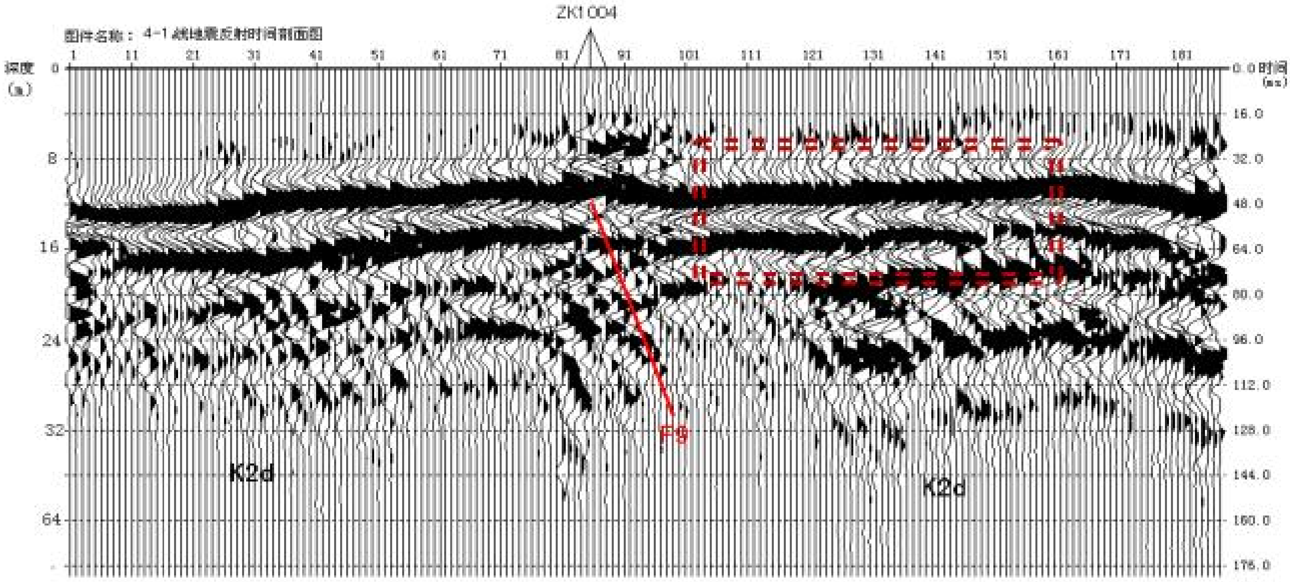
2. Cross-hole CT method exploration in metal ore void areas





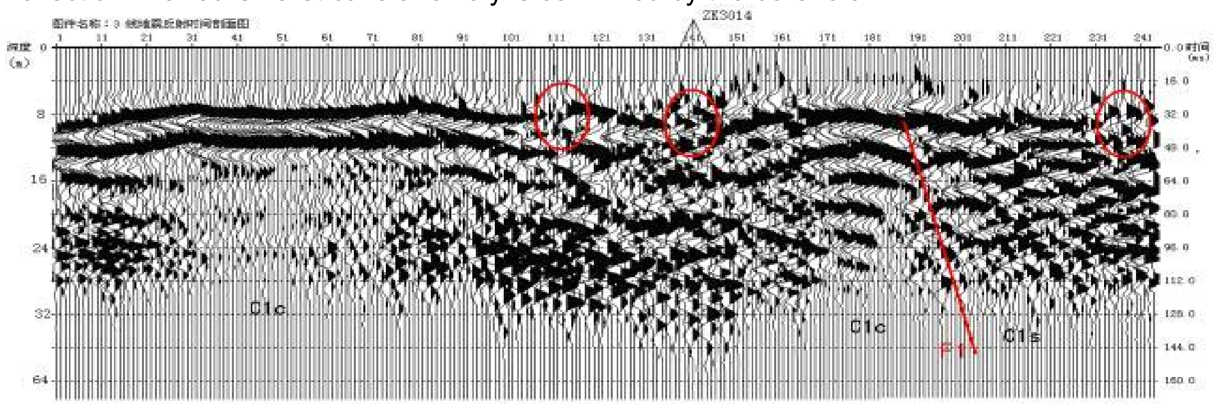
3. Reflection wave method survey for karst collapse

Taking a survey of karst ground collapse and ground subsidence geological disasters in a certain area as an example, this introduces the application of the engineering seismic reflection method in the investigation of karst ground collapse and ground subsidence geological disasters. The purpose of using the engineering seismic reflection method is to essentially ascertain the structural trend, burial depth, and its developmental degree within 70m underground in the surveyed area, providing a basis for the next step in the treatment of the geological disaster.

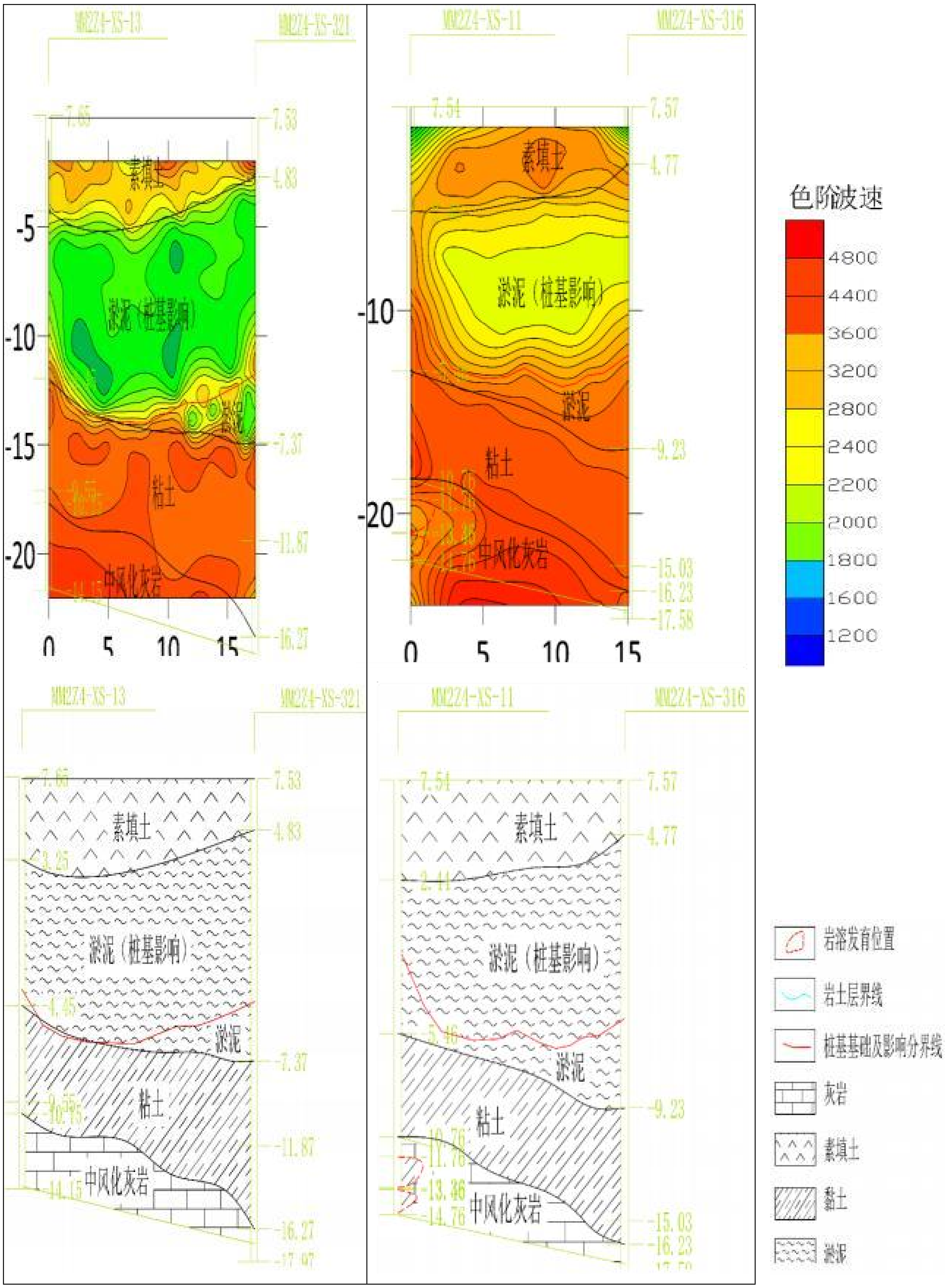


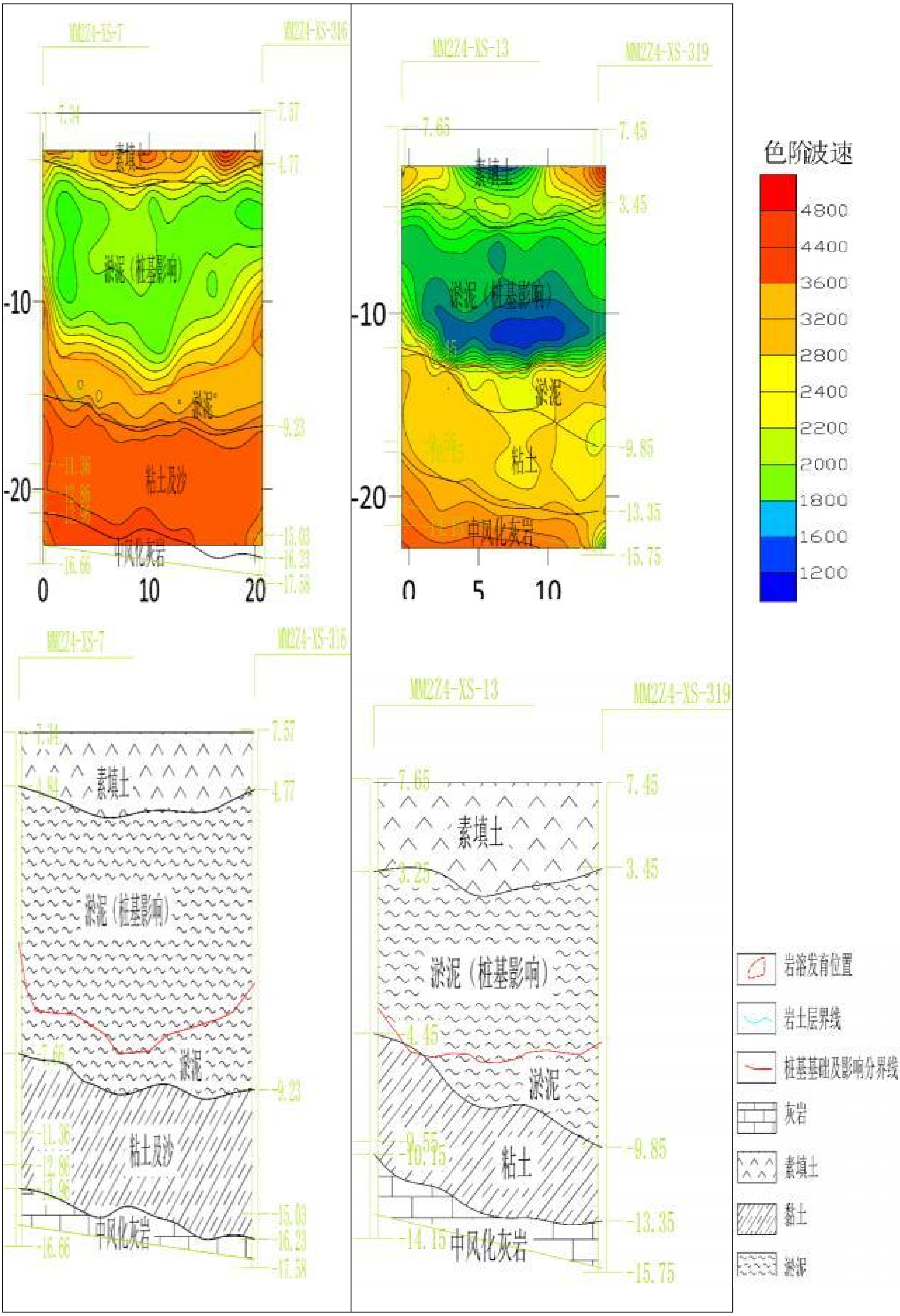
The anomaly on this survey line is attributed to a fault, contact interface, or fracture zone anomaly, located at 820m. The anomalous feature is the discontinuity of the reflection wave's same-phase axis, and the cause of the anomaly is inferred to be the F9 fault. The verification borehole number is ZK1004, where structural conglomerate rock was observed at a depth of 23.20-23.80m. The test results confirm that Anomaly A is caused by a fault.

The anomaly in this section is attributed to soil holes and karst (including loose collapses), located at 230 -240m. The anomalous feature is that the reflection wave exhibits low amplitude and long periods, and the cause of the anomaly is inferred to be a rock (soil) hole. The verification borehole number is ZK3014, and the drilling test result shows an unfilled karst cave at a depth of 19.85-21.90m. The shallow seismic reflection inferred C karst cave anomaly is confirmed by the borehole.



4. Elastic wave cross-hole CT survey in a specific location.




MM2Z4-XS-7
MM2Z4-XS-316
MM2Z4-XS-13
MM2Z4-XS-319
素填土
淤泥（桩基影响）
淤泥
粘土及沙
粘土
中风化灰岩
色阶波速
4800
4400
3600
3200
2800
2400
2200
2000
1800
1600
1200
岩溶发育位置
岩土层界线
桩基基础及影响分界线
灰岩
素填土
黏土
淤泥