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# Study of "bright spots" in seismic reflection data

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**Abstract** "bright spot" on reflection seismic profile has been regarded as one of the important indications of oil and gas, and it has been widely used in the oil and gas exploration. Moreover, with the development of new technologies, "bright spot" technique has been gradually applied to the exploration of coal, underground water and other fields, and also in the research of deep structure of the earth. Based on the reviewing of published literatures, the authors described the structural features and generation of "bright spot" on seismic profile for energy resources exploration and crustal-scale deep seismic reflection profiles, and further summarized the applications of the "bright spot" technique in energy resource exploration and deep structure research.
**Key words:** seismic reflection; bright spot; resources and energy; deep structure

## 1 Introduction

The so-called "bright spot" on the seismic profile means the local highamplitude anomaly on the seismic reflection profile (Lu *et al.*, 2009). With the development of science and technology, based on the true amplitude technology combined with the polarity reversal of the strata, dipole phase and velocity anomaly effect, the "bright spot" technique is becoming more and more mature and has been widely used in the domestic and international exploration (Liu, 1985). These reflective seismic profiles for energy resource exploration are typically used in the upper crust sedimentary basins. Since 1980s, due to its high-resolution detection capability, reflective seismic technology has gradually become a pioneering technology to reveal the internal structure of the Earth, and one of the most powerful methods in the detection of crustal structure. A number of significant "bright spots" of strong amplitude reflections have also been found on the deep seismic reflection profiles at the crustal scale which were implemented globally (Lu *et al.*, 2014). Different from the "bright spots" in the sedimentary basins of the shallow crust which may represent the occurrence of oil and gas, the strong reflection "bright spot" found on these deep seismic reflection profiles may be caused by the partial melting, fluid or magmatism related to the plate residuals and crustal thickening during plate subduction (Lü *et al.*, 2010).

This paper aims at systematically studying of the "bright spot" structure of deep seismic reflection profile and of seismic data on resources exploration, summarizing the scope and cases of the application of "bright spot" technology, and discussing the physical and deep geological process related to the "bright

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spot”.

## 2 Application of “bright spot” in energy and resources exploration

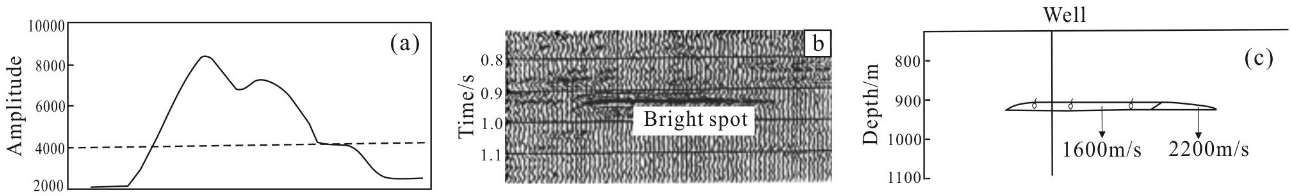
### 1.1 Application of “bright spot” in petroleum exploration

In Symposium on Geophysics and Geology held in America in November 1973, a method of directly identifying lithology and detecting hydrocarbon based on reflection seismic was put forward. A typical example is in the Gulf of Mexico. In a seismic profile with anticline structure in the Gulf of Mexico processed with relative amplitude preservation, a local amplitude anomaly, i. e. “bright spot” was confirmed to be a gas-bearing reservoir. The success rate of wildcat wells in the hydyocarbon exploration in the Gulf of Mexico was significantly improved with “bright spot” technique. The “bright spot” was interpreted as a direct indication of gas-bearing sandstone, a direct hydrocarbon indicator.

The technology of “bright spot” has been gradually developed since 1970s, but the limitations of it have emerged (Wang, 1984; Pan, 1988) due to different geological conditions and physical properties in different areas. “bright spot” or dim spot do not always exist in petroliferous sandstones. Especially in complex geological conditions, the “bright spots” are possibly not indication of hydrocarbon, and the dim spots are not definitely signs of hydrocarbon in terristrial formation. The conclusion must be made based on comrehensive analysis and interpretation. Nevertheless, in the later petroleum exploration, many successful cases of detecting hydrocarbon with “bright spot” emerge.

The first successful case with “bright spot” under progressive gas exploration and development program in the Shengli Oilfield occurred in Gunanken-23 fault block and Sanhe Village. The first field development plan of shallow gas reservoir under the progressive exploration and development program was achieved in Gunan-Sanhe Village through identifying gas reservoir with “bright spot” and efficient development drilling, creating a new pattern of developing shallow gas reservoir (Sheng *et al.*, 1999).

As shown in Fig. 1, seismic profile shows the obvious feature of gas “bright spot”. Near gas zone at 0.93 s in the “bright spot”, the seismic amplitude is above 4 000, with clear characteristics of dipole phase and polarity reversal. In the G-log profile, the “bright spot” corresponds to a low-velocity zone immediately above a high-velocity zone, which is consistent with variation of vertical velocity in gas zone.

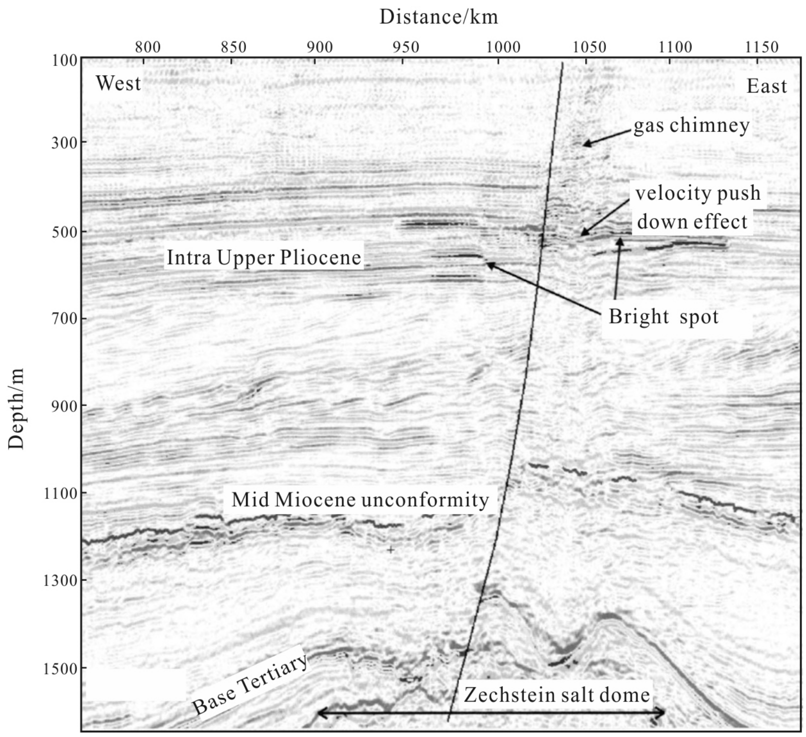



(a) Amplitude distribution; (b) seismic profile; (c) gas reservoir profile

**Fig. 1 Distribution of gas reservoir in line 613.5 of Shengli Oilfield** (Sheng *et al.*, 1999)

The gas chimney structure is clearly outlined on 3D seismic with “bright spot” in North Sea area in Netherlands (Barthold & Ruud, 2003). In the seismic profile of good quality, the chaotic seismic feature occurs in the position where the gas chimney appears, with sharply reduced amplitude, which is in sharp contrast to strong reflections in the bright on both sides, making it easy to locate gas chimney. The sealed gas reservoirs are then detected through effective study.

Although the technology of “bright spot” plays a key role in petroleum exploration and even becomes one of the hydrocarbon indications in seismic reflection. The “bright spot” could be caused by the special lithology without hydrocarbon, e. g. sand body, basalt, igneous rock conglomerate, and the “bright




(a) Amplitude distribution; (b) seismic profile; (c) gas reservoir profile

**Fig. 2 Structure of "gas chimney" and reflection of "bright spot" in North Sea area in Netherlands (Barthold & Ruud, 2003)**

spots" are not always related to hydrocarbon.

## 2.2 Application of "bright spot" in coal exploration

Since the "bright spot" was widely applied in petroleum seismology and a breakthrough was achieved in the search of hydrocarbon in 1970s, the coal seismologists have conducted research on the geophysical characteristics of coal bed reflections and the possibility of identifying coal bed based on dynamic characteristics of reflection wave. At that time, the geophysical company under the Ministry of Coal Industry of the People's Republic of China investigated relationships between characteristics of reflection wave amplitude and the "bright spot" in coal seam. The condition of forming "bright spot" exists in T3 coal seam in JN area. After correlating with drilling data, it is confirmed that the brightest reflection on normal polarity seismic corresponds to T3 coal seam (Liu, 1985).

With the development of the theory on coal-generated hydrocarbon in recent years, it is believed that the hydrocarbon could be generated in the coal, and part of gas is absorbed by the coal seam. The coal seam has low seismic velocity and density, which forms a strong acoustic impedance contract with other strata. Therefore, it is possible that the coal seam appears as "bright spot" on seismic and can be detected.

The reflection characteristics of coal seam as "bright spot" on seismic profile were summarized by Li *et al.* (1994), who concluded that a series of reflections with strong amplitude and good continuity exist in the upper Jurassic in most of seismic profiles in Xingshan depression in Songliao Basin, and the reflections are calibrated as coal seams in synthetic seismogram. Due to strong transmission loss in the coal-bearing interval, the ground-based geophones could only receive very weak energy of reflected wave below the coal-bearing interval, and it is difficult to continuously trace the reflectors below coal seam (Fig. 3).

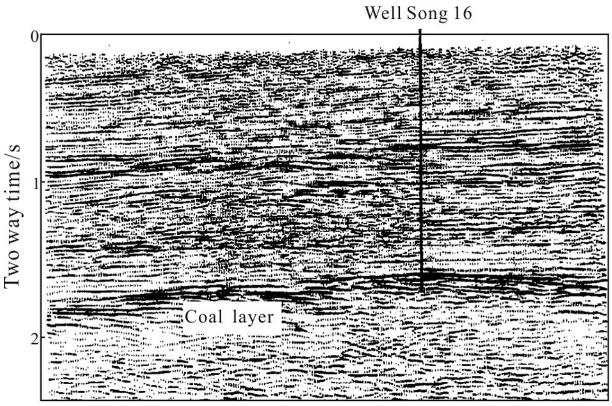



**Fig. 3 "bright spots" in seismic profile of coal layer in Songliao Basin** (Li *et al.*, 1994)

### 2.3 Application of "bright spot" in groundwater resources exploration

With constant improvement of the seismic exploration technologies, "bright spot" are gradually applied in exploring underground water and to define the stratigraphic structure, lithology and porosity.

An example of searching underground water in the arid regions in West China is described in Fig. 4, which shows that the DF3 fault fracture and breakage location correspond to the relatively strong energy of reflected seismic wave – "bright spot", which provides strong support for predicting water-bearing fault fractures. On seismic it shows that the depth of the base of upper Cretaceous (K2) is about 157 m and is 156 m in actual drilling, with an error of only 1 m. DF3 normal fault is identified at 364 m on seismic, and 354 m in drilling, with error of 10 m. The well yields water of 3 500 $m^3/d$, confirming validity and reliability of seismic speculation.

Application of "bright spot" technology in exploring ground water shows that seismic not only plays an important role in research on geological structure and stratigraphic sequence, but also provides a new method for searching deep groundwater in arid areas in western China with specific characteristics of seismic wave corresponding to groundwater.

### 2.4 Seismic exploration of metal deposits

Research on physical properties of ore body indicates that there exist a lot differences in impedance

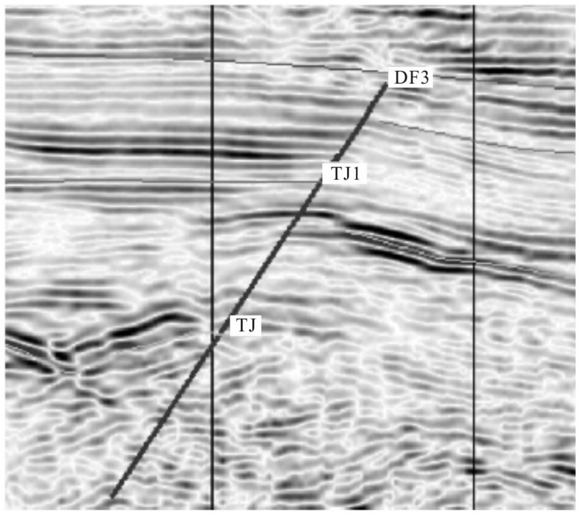



**Fig. 4 Example of exploring groundwater with "bright spot"** (Gao *et al.*, 2013)

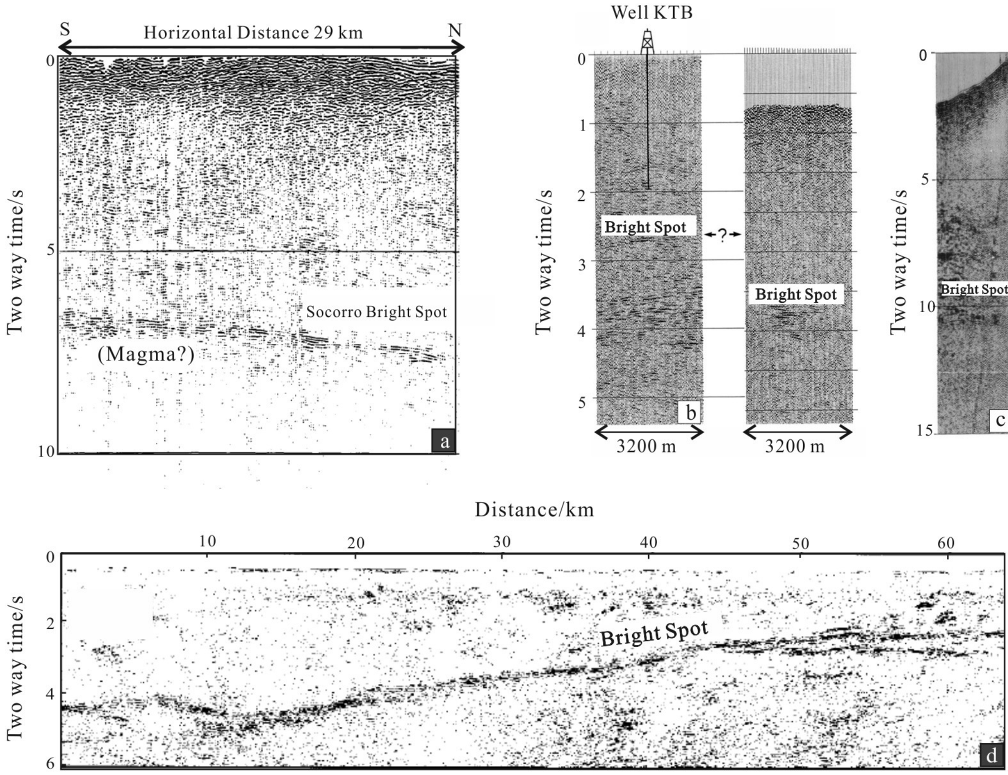
between deposits and their surrounding rocks. However, it is still not sure whether the ore body can results in detectable "bright spots" as hydrocarbon does (Lü[e]t *al.*, 2010). In present exploration of metal deposits, the seismic reflection method is mainly applied in the defining of geological structure (ore-controlling structure or ore-breaking structure) related to metal deposits, delineation of faults, the form of ore-bearing structure and bedrock relief, and in the detection of sedimentary metal deposits. It is used as indirect indicator in the exploration of metal deposits (Yan & Jing, 2011).

## 3 "bright spot" helps to understand deep structure of the earth

Not all "bright spots" indicate hydrocarbons. With application of deep seismic reflection profile at crustal scale, a number of significant "bright spots" of strong amplitude have been detected globally. Lu *et al* (2014). systematically summarized the "bright spots" in deep seismic reflection profiles and discovered that the continental deep reflection "bright spots" are mainly occurred in the North American continent and the continent of Europe. In Asia, they are sporadically distributed in the south of the Qinghai-Tibet Plateau, the middle of Japan island arc, the southeast of Australia, and the west of South America.

According to the published literatures, the deep seismic reflection "bright spots" are usually interpreted as magma "bright spot", non-magmatic fluid, layered lower crust, and mafic batholith.

It is detected in the deep seismic reflection profile from COCORP exploration program that a seismic reflection event of significantly enhanced amplitude occurs in a depth of 20 km north of Socorro, New Mexico, USA (Fig. 5a). It is believed that "bright spot" reflection in this area is resulted from magmatic activity (Brown, 1991), and is called magma "bright spot". But S-wave in the solid-fluid interface is not detected in German KTB drilling site (Fig. 5b), which indicates that the "bright spot" reflection is possibly caused by fracture water or variation of quartz content in the crust (Lüeschen, 1994).




(a) Magma "bright spot" (Brown, 1991); (b) non-magmatic fluid (Lüeschen, 1994); (c) layered Lower Crust (Klemperer *et al.*, 1986); (d) mafic sills (Mandler & Clowes, 1997).

**Fig. 5 Types of "bright spot" on deep seismic reflection profile**

One of the most important achievements of deep seismic reflection profile is the lower crust with strong reflection, and distinct Moho of strong reflection overlying non-reflection mantle (Matthews & Cheadle, 1986). There are several interpretations on reflections of layered lower crust, including intercalation of lithology in crust and mantle, ductile high strain zone (mylonite), fractures filled with liquid, and intrusive basaltic bedrock (Klemperer *et al.*, 1986). The layered lower crust revealed by deep seismic reflection in North American continent is shown in Fig. 5c.

A large difference in density and seismic wave velocity between magma and surrounding rocks during cooling will result in a strong reflection interface. Invasion of mafic (e. g. basalt or gabbro) or ultra-mafic (e. g. dunite) material to the base of continent will produce "bright spot" of strong reflection. The mafic rock beneath Wollaston Lake in Canada is characterized by strong near-horizontal seismic reflection (Fig. 5d), with a scale up to hundreds of kilometers (Mandler & Clowes, 1997).

# 4 Conclusion

The “bright spot” technology has been developed a lot in past 40 years, and it not only promotes exploration of hydrocarbon, coal, groundwater, etc., but also achieves effective application in research on deep structure of the earth. But it still has some limitations.

In hydrocarbon exploration, it is difficult to estimate gas saturation with “bright spot” or amplitude anomaly, since there is little difference between amplitude anomalies resulted from reservoirs filled a small amount of gas and reservoirs fully filled with gas. In this situation, the detected gas possibly has no industrial value. Furthermore, not all “bright spots” are indications of hydrocarbons, and not all oil and gas reservoirs show “bright spot”. Overlain by shale, the oil and gas accumulation zone may not show “bright spot” but dim spot, which is due to weakening amplitude. In practical work, the researchers must be fully aware of these limitations and apply “bright spot” technique through analysis of limitations and different geology conditions, promoting the application of the technology in energy and resource exploration.

In terms of understanding deep structure, it is far from enough to carry out research with amplitude, and it is necessary to study characteristics of P-wave frequency, polarity, S-wave attenuation, and even electric structure and geological background of “bright spot” in the seismic reflection profile, so as to make more reasonable explanation of deep seismic “bright spot” reflection.

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