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Ground movements caused by deep underground mining in Guan-Zhuang iron mine, Luzhong, China

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ABSTRACT

It is difficult to calculate the accurate ground movement due to deep underground mining because of the complexity of the geotechnical environment. Guan-Zhuang iron mine is a pillarless sublevel caving mine operated by Luzhong Metallurgical Mining Company, south-east of Jinan, PR China. It mines the Zhangjiawa Seam at a depth of approximately 520 m. Although the towers are outside the conventional 'angle of draw' subsidence influence criteria, and have seen only negligible vertical displacement as a result of deep mining, there has been widespread evidence of regional horizontal displacement of the land surface, large distances away from the mining area. Possible explanations of these displacements include one or a combination of mechanisms such as pre-mining stress relaxation, regional joint patterns, soft rock strata, displacement toward active goaf areas. Luzhong Metallurgical Mining Company have been making precise measurements of distances near the shaft towers in the Guan-Zhuang iron mine since 2003. The results show horizontal displacements of up to 96 mm occur even when underground mining is about 0.8 km from the survey displacements. From an analysis of these and other survey results it is concluded that mining effects extend a long way from deep mining. The results also show that ground horizontal displacements are typically at least as great as the vertical component, that the maximum horizontal displacement occurs soon after undermining.

1. Introduction

Guan-Zhuang iron mine is one of a number of underground iron mines to the eastern and south-east of Jinan, operated by Luzhong Metallurgical Mining Company, which mines the Zhangjiawa iron orebody at a depth of approximately 520 m using the pillarless sublevel caving method. The sublevel height is typically about 10–12.5 m. The pillarless sublevel caving workings in these mining areas are at depths of about 410–520 m, and displacements were being measured 0.8 km or more away from an active sublevel. Fig. 2 shows one example of these measured displacements and it can be seen that in this case lateral displacements of about 30 mm were measured about 0.8 km away from a sublevel panel being extracted at a depth of about 530 m. There were no measurable vertical displacements at this distance. These lateral displacements have been termed "far field effects" (Reid, 1998; Hebblewhite, 2001; Blodgett et al., 2002; Li et al., 2003).

The magnitude of the measured horizontal displacements, and the fact that some of these displacements have commenced when mining was as far as 0.8 km from the survey monuments, has surprised many observers and lead to questions about whether the displacements have been due to mining, or to a tectonic mechanism, or to a combination of factors. When expressed in terms of an "angle of effect", 0.8 km is equivalent to an angle in excess of 38°.

The paper is particularly focused on the regional displacement behaviour of the ground surface, including the towers, and the development of possible geomechanical explanations for such behaviour.

2. Geotechnical and surface environment of mining area

In Guan-Zhuang iron mine, the overlying strata consist of a series of sandstones, pelitic siltstones; siltstones, gritstones, hornstones, marbles, skarns and claystones. Some of these strata are quite massive and thickly bedded, but with dominant vertical jointing persisting through most horizons. The strata are generally subhorizontal. The soil in the vicinity of the displacements is generally thin and sandy (Alluvium). The stratigraphy of the Zhangjiawa region (Zhangjiawa iron basin) is summarized in the general stratigraphic column shown in Fig. 1.

There are a number of major and minor geological structures running through the area, typically normal faults, or fault regions, which generally have a northeasterly strike. This direction also coincides with the dominant joint direction in the pelitic siltstone,

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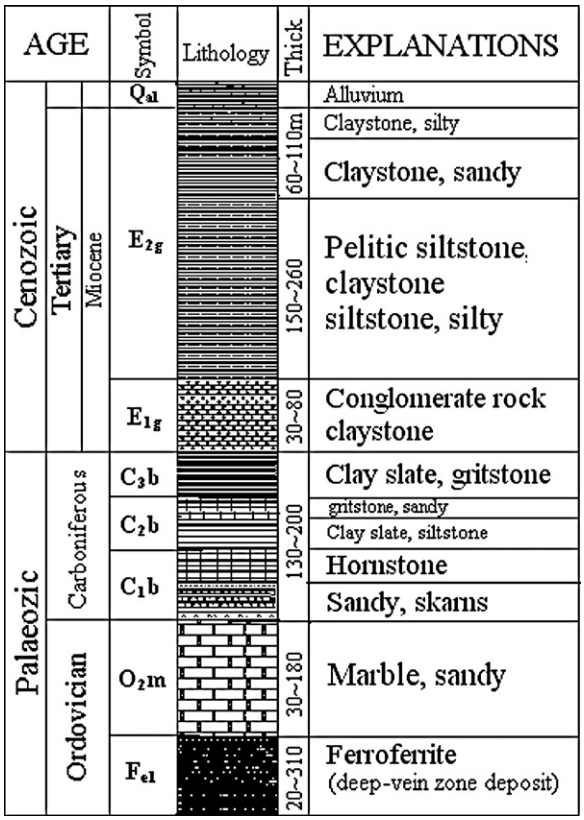

Fig. 1. Generalized stratigraphic section of the Zhangjiawa iron basin.

in the Guan-Zhuang iron mine region. A secondary, northeast trending joint set creates a blocky nature to the surface pelitic siltstone. A feature of the horizontal stress in the Zhangjiawa iron basin, and the region around Guan-Zhuang iron mine in particular, is the high ratio of horizontal to vertical pre-mining stress. A stress ratio in excess of 1.3:1 has been measured in a number of locations at Guan-Zhuang iron mine, with a predominant northwest orientation for the major principal stress direction. This results in pre-mining horizontal stress levels of in excess of 24 MPa in some parts of the mining area.

Fig. 2 is a plan showing the location of the current Guan-Zhuang iron mine workings (and in particular, mining areas E-270 and N-330), together with the surface topography and civil infrastructure on the surface. This diagram indicates that the closest distance between the shaft tower and the goaf edge of both E-270 and N-330 was in excess of 400 m. The other surface infrastructure shown in Fig. 2 includes the Jiqing Highway – the major, six-lane highway connecting Jinan and Qingdao, and the Main Southern Railway, in the north east corner of the plan. The nature of the surface land coverage and land use consists of wooded areas, cleared in places for light industrial/agricultural and residential use. Mining in this vicinity is therefore strictly controlled and very carefully monitored in relation to ground subsidence and environmental impact due to deep underground mining of iron ore body.

A particular concern for the extraction of E-270 and N-330 was the potential subsidence impact on the twin shaft towers. Previous experience had indicated that severe incompetent beds in other mining areas of this lease, and elsewhere, could result in significant 'anomalous' subsidence behaviour. This included significant horizontal tower deformation and large-scale, regional, horizontal displacement due to deep underground mining of iron ore body.

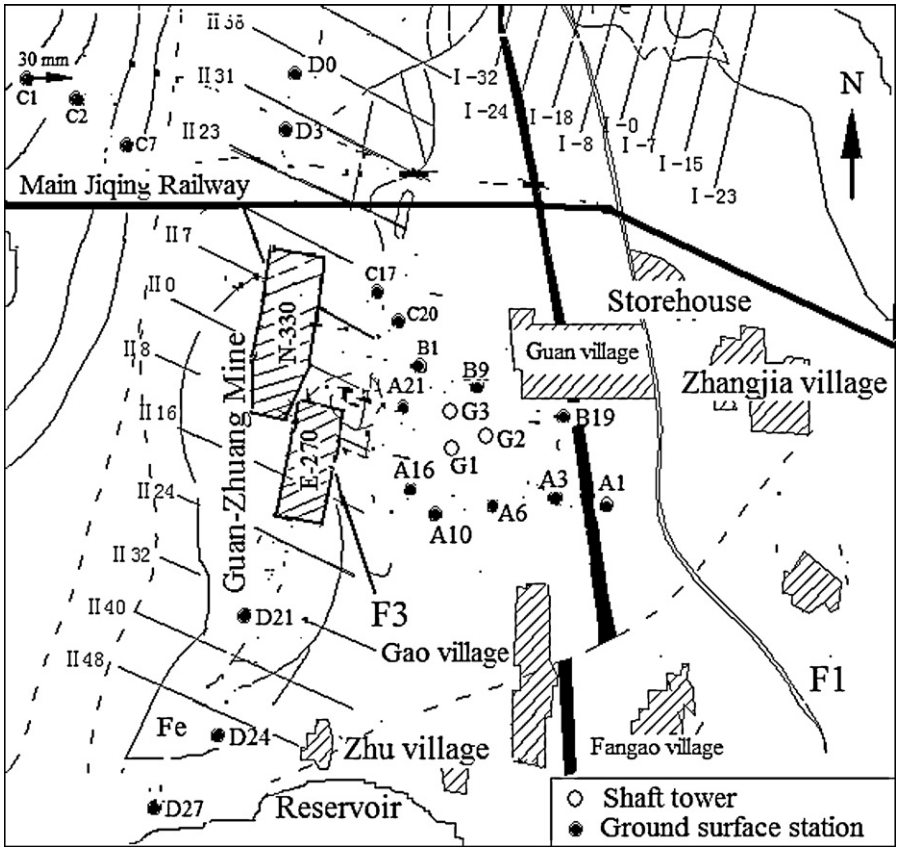

Fig. 2. Plan of Guan-Zhuang iron mine, surface features (I-××, II× are geological prospecting lines).