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Observation of explosion pits and test results of ejecta above a rock avalanche triggered by the Wenchuan earthquake, China

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A B S T R A C T

The 12 May 2008 Wenchuan earthquake in China triggered many rock avalanches that disrupted the transportation system and thereby caused additional fatalities. In this paper, several lines of evidence were forwarded to show that the rock avalanches, distributed along some highly destructed areas, i.e., the main seismic fault (F_2), had been enhanced by natural explosions and fires immediately after the main earthquake. Burned rock samples from the explosion pits near the highly destructed parts of Shuijingyan (SJY), north of Beichuan County, were collected and analyzed in the laboratory. The brown porous ejecta were featured by intensive thermophili degradation because they had high content of polycyclic aromatic hydrocarbons. Microstructure and composition analyses indicated that four samples, a mixture of reef limestone and manganese ore, were carbonate manganese and carbonaceous rock, which generally is buried at 500–2000 m depth. With high content of polycyclic aromatic hydrocarbons, the brown porous ejecta were believed to have reached a highly thermal degradation process compared with surrounding and intact counterpart rocks.

1. Introduction

The devastating Wenchuan earthquake of Mw = 8.3 (according to Chinese Earthquake Administration-CEA; Mw = 7.9 according to the USGS) occurred at a hypocenter depth of 19 km on 12 May 2008. At least 70,000 people were killed and nearly 5 million persons were left homeless in major cities aligned along the western Sichuan basin in China (Stone, 2008). Direct economic losses amounted to 845.1 billion Renminbi (RMB) (Shi, 2010). The epicenter was located 80 km west-northwest of Chengdu, the capital city of Sichuan. Most of the disasters were caused by enormous rock avalanches that traveled at speeds of hundreds of kilometers per hour and were the most deadly landslides in terms of loss of life. For example, Donghekou rock avalanche traveled about 2.6 km, buried four villages, and caused more than 780 deaths (Qi et al., 2011).

As for long distance movement and distal distribution affects with local extreme heat in catastrophic landslide deposits in the Himalayas, a small amount of carbonate appeared to have been calcined by frictional heating, presumably at the base of the initial sliding masses (Hewitt, 1988). The high energy concentration resulting for the zone near the gliding surfaces points to self-lubrication by transformed rock as fundamental tribological mechanics in central Europe (Erismann, 1979). During the earthquake, imminent luminescence phenomena, with lighting and rupturing, were studied by different experts (Ma, 1974; Losseva and Nemchinov, 2005), which reflected a complex physical process in the main shaking.

In the epicenter of the Wenchuan earthquake, the authors found some circular pits appearing on the deposition surface in the configuration of a stringed bead. Tremendous fractured limestone and dusty gray-black carbonaceous rocks could be seen at the margins of those pits. Huge amounts of loose and crumbled materials, which were very different in shape and form from those of the common earthquake-induced landslide, existed at the distal and proximal ends of the rock avalanches. Field investigations were carefully made and samples were collected from several spots in the Wenchuan main quake zone for microstructural and chemical analysis to study their formations. At the Shuijingyan location (SJY), in northern Beichuan County, 17 tree trunks (burned at the ends) erupted out of the ground. The C^{14} age of a tree trunk specimen is over 5000 a B.P. During the main shock, local survivors heard some deep bangs lasting for about 2 min, immediately followed by rock avalanches near the epicenter. The other four explosion sites are located along the main seismic fault F_2, lying within the X-XI intensity contour lines (Fig. 1).

Two updated discoveries clarified that methane emissions were abnormal after the main shock. Huge amounts of gas were monitored in a deep drill hole (WFSD-1) located at a depth of 585–600 m in the fault F_2 aftershocks. In the gas mixture, methane was featured by prompt uplift at those moments (Wang, 2011). Another case was the hot (45 °C)

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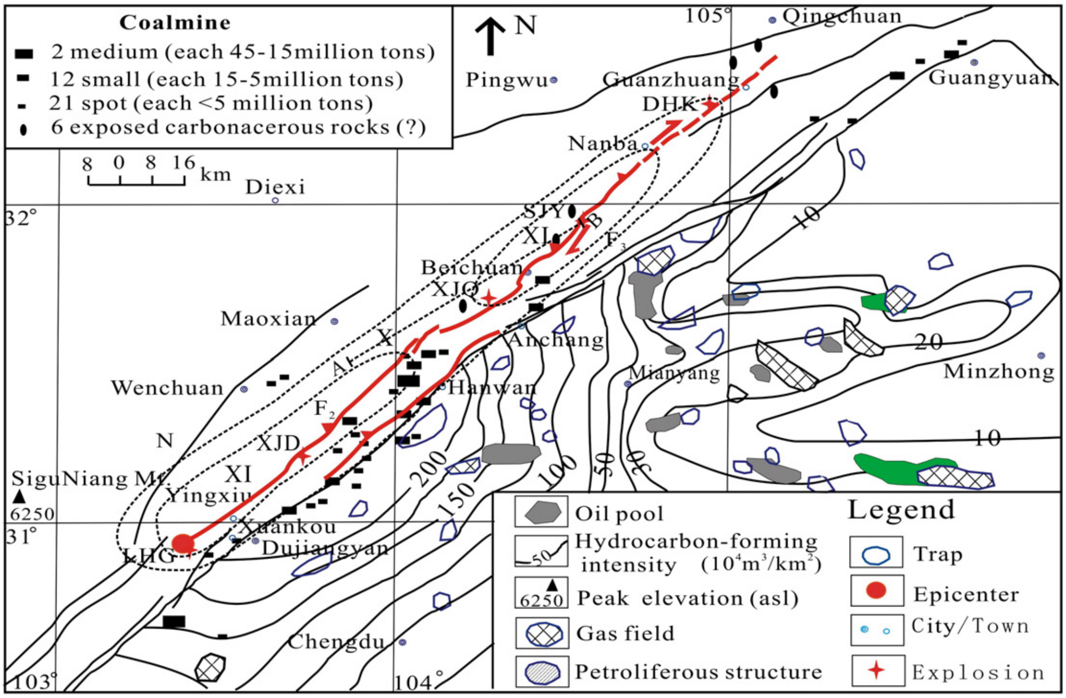

Fig. 1. Distribution of coal mines, oil and gas fields at Longmenshan area. Coal mine (modified after RGT2, 1966, 1970; GBS, 1975). Oil pool and gas field (Tian et al., 2008). Gas pool and gas-bearing structure (Liu et al., 2005; Cai and Yang, 2011). Surface rupture (Xu et al., 2008). Meizoseismal zone (Li et al., 2008). Explosion places from north to south: DHK—Donghekou; SJY—Shuijingyan; XJQ—Xiaojiaqiao; XJD—Xiejiadianzi; LHG—Lianhuaxingully. Red lines indicate co-seismic surface ruptures (Xu et al., 2008). Dashed line is contours of seismic intensity (X–XI). The blue line bounded area represents distribution of traps and explored gas field.

spring and natural gas emission (with methane at a content of 66%) at the DHK site just above the F_2 (Wang et al., 2009).

In this paper the authors present observations of pits and test results of ejecta samples collected in the SJY site. In the end, conclusions associated with gas explosions enhancing rock avalanches are put forward.

2. Geological setting and sample collection

One of the biggest rock avalanches in the epicenter was SJY, north of the town of Beichuan and above the main seismic fault F_2, characterized by local gas enrichment distributed as beaded forms at depths 200 m to 5000 m in T_3x (Wang, 2003). In fact, the overpressure center in the Longmenshan area was not in accordance with the gas generation center of the T_3x, the former together with gas fields was at Mianyang (Cai and Yang, 2011), also close to the epicenter as well as SJY (Fig. 1).

The Qiujiahe Group of the Lower Cambrian system (bq) contains a lenticular manganese ore layer (manganiferous carbonaceous shale) at a depth of about 2000–2500 m, while the second sub-group of the Maoxian Formation, the Silurian system ($S_{2-3}mx^2$), contains honeycomb porous reef limestone at depths of 500–1000 m (Fig. 2). Lab analyses showed that the two layers supplied the mixture ejecta (S01), plentiful scattered carbonaceous shales and limestones (Table 1).

The rock avalanche in SJY was 10–50 m thick, 500 m long and 500 m wide; and at its distal end a landslide dam was formed with explosion-like swellings. Some circular pits 3–5 m deep appeared and were covered with black carbonous rocks, corroded limestones and gray slates

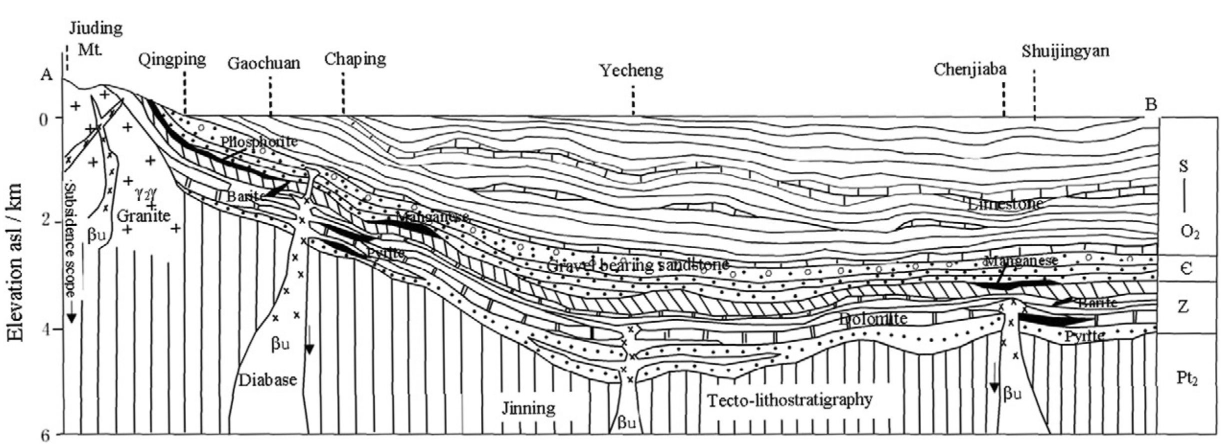

Fig. 2. Geological profile in the SJY region (modified after RGT2, 1970). The Sinian system (Z), with a thickness of over 1500 m, is composed of carbonate rock, silica rock, manganiferous layer, as well as basic veins and sills. This stratum is rich in ore deposits such as sedimentary manganolite, hydrothermal barite. The Cambrian system (Є), with a thickness of less than 1000 m, is composed of sandstones, siltstones and gravel bearing coarse sandstones. The Middle Ordovician to Silurian system (O_2-S), with a thickness over 3000 m, is mainly composed of shale, with 1–3 intercalated limestone beds. The reef limestone occurred in the middle to upper Silurian system (for location of the profile A–B, see Fig. 1).