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## Short Note

# Subsurface fire and subsidence at Valle del Potosí (Nuevo León, Mexico): Preliminary observations

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## Abstract

Since the last three decades, Valle del Potosí basin (western part of Nuevo León) has been experiencing subsurface fire and subsidence. Preliminary field observations relate the subsurface fire to smoldering of a peat layer at 200-280 cm depth. Subsidence was caused by the associated volume reduction as a result of peat burning. We hereby present the chemical composition of the peat layer and report about the possible reasons of subsurface fire and subsidence.

Keywords: subsurface fire; subsidence; smoldering; peat; Nuevo León.

## Resumen

*Desde las últimas tres décadas, la cuenca de Valle del Potosí (parte occidente del estado de Nuevo León) ha sido testigo de incendio subsuperficial y subsidencia. Las observaciones preliminares de campo relacionan el incendio a la combustión latente de una capa de turba ubicada en una profundidad de 200-280 cm. La subsidencia fue causada por la reducción de volumen asociado al incendio de turba. Se presentan la composición química de la turba y se reportan las posibles razones del incendio y de la subsidencia.*

*Palabras clave: incendio sub-superficial; subsidencia; combustión latente; turba; Nuevo León.*

## 1. Introduction

Valle del Potosí basin is located in the arid western foothills of Sierra Madre Oriental Mountains in the state of Nuevo León. It is present at ~100 km south of Monterrey city and ~30 km west of Galeana town (Figure 1). During the last three decades, the basin has been experiencing subsurface fire and subsidence. Subsidence of the basin has affected the agricultural activity and local economy as the basin surface was used for cultivation. Furthermore, the

local population (*i.e.* village of Catarino Rodríguez) has been exposed to the smoke plumes coming out through the fissures. In this short publication, we show the preliminary field observations and chemical composition of subsurface sediments in order to explain the fire source and reasons of subsidence.

## 2. Field observation

During the night and early morning, the smoke plumes

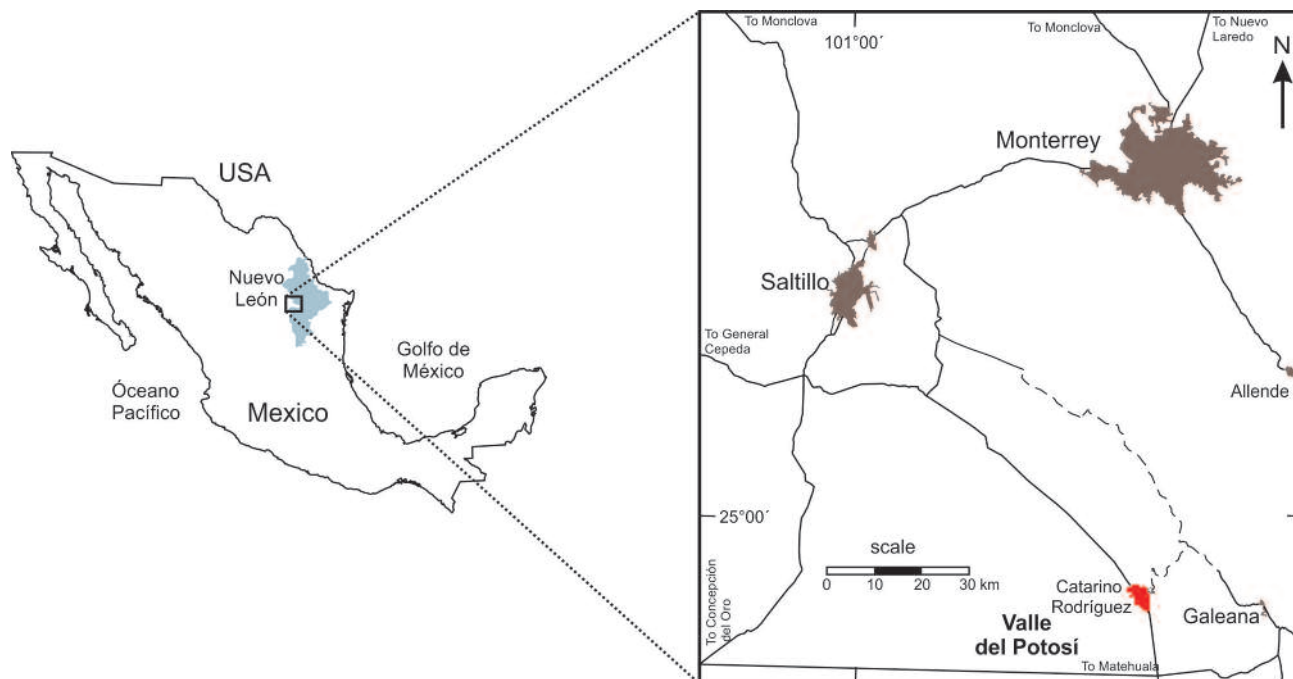


Figure 1. Basin of Valle del Potosí is located in the western part of Nuevo León state in the northern Mexico.

are clearly visible in different parts of the basin (Figure 2A). The Google Earth imagery estimates that at least  $\sim 18$  km<sup>2</sup> of the area has been subjected to subsidence. There is up to 5 m of subsidence in some parts of the basin (Figure 2B). In several sites within the basin, a number of almost vertical fissures are present (Figure 2C). The fissures are 10–20 cm wide and reach a depth of up to  $\sim 2$  m. Most of these fissures have a deposition of yellowish sulfur crystals on the surface (Figure 2D). Different trenches were dug in the unaffected eastern part of the basin and all of them reveal the presence of a peat layer at  $\sim 200$  cm depth (Figure 3A). During the process of sample collection along the pits, we observed smoke emissions from the peat layer (Figure 3B). This peat layer is  $\sim 80$  cm thick (between 200 and 280 cm depth) and is intercalated with lacustrine calcareous clay (bottom, Figure 3C) and calcareous silt (top). Over the years, the subsurface fire has burnt many trees (Figure 3D) and the people living in the nearby villages are exposed to the emission of smoke plumes.

### 3. Chemical data

A total of 16 samples were collected at every 5 cm interval from the peat layer. The concentrations of organic carbon, total nitrogen, and total sulfur were measured in Thermo Scientific HiPerTOC solid analyzer and Perkin Elmer Series II CHNS/O elemental analyzer. The bottom part of the peat layer (240–280 cm) has more organic carbon (8.5 – 20.8 %), nitrogen (0.6 – 1.0 %), and sulfur

(0.4 – 3.4%) compared to the upper part (200–240 cm). The upper part of the peat layer has 1.7 – 4.8 % organic carbon, 0.3 – 0.6 % nitrogen, and 0.3 – 0.7 % sulfur (Figure 4).

### 4. Reasons for subsurface fire and subsidence

In the last two decades, different researchers have reported multiple events of subsurface fire in Indonesia, Malaysia, Russia, Italy, Spain, UK, Australia, and Africa (Davies *et al.*, 2013; Martinelli *et al.*, 2013; Minayeva *et al.*, 2013; Moreno and Jiménez, 2013; Dommain *et al.*, 2014). The subsurface fires were related to slow, low temperature, and flameless combustion or peat smoldering. Peat deposits absorb 10–30 times the amount of water compared to its dry mass (Minayeva *et al.*, 2013). However, the decline in rainfall amount (natural phenomenon) as well as the excessive and unregulated exploitation of ground water (anthropogenic activity) reduces the moisture content of the peat (Moreno and Jiménez, 2013). The above mentioned studies have linked the initiation of subsurface fire to the self-heating and spontaneous combustion of dry peat during the drought periods and the agricultural related burning activities. The continuation of subsurface fire for several years was associated to the penetration of atmospheric oxygen through the existing fissures as the falling groundwater table expanded the unsaturated vadose zone.

In Valle del Potosí, the farmers have witnessed a fall in the water table from 1–2 m below the surface to more

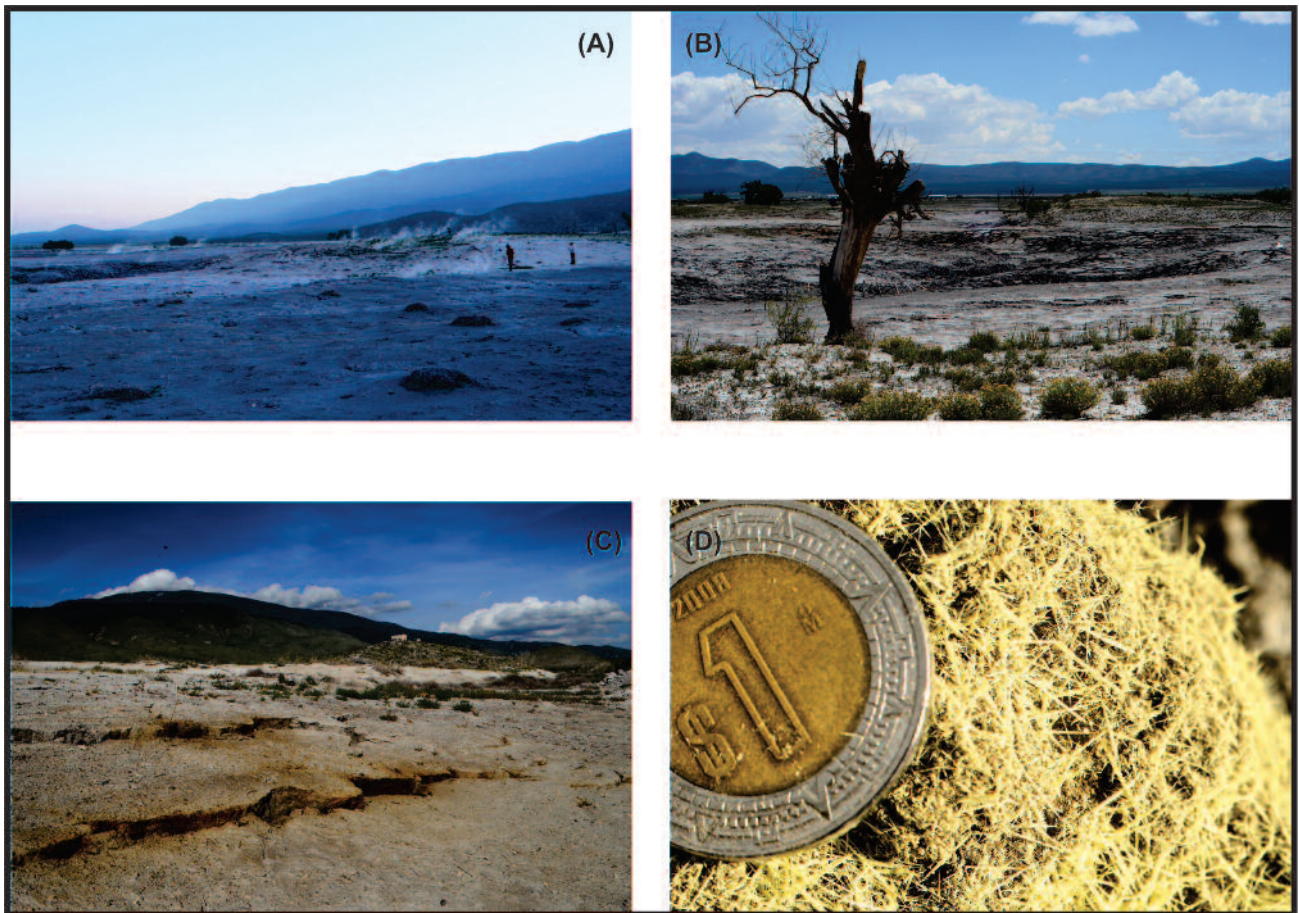


Figure 2. Field observations of (A) smoke plumes visible during early morning in different parts of the basin, (B) subsidence observed in the eastern part of the basin, (C) some of the surface fissures allowing the penetration of atmospheric oxygen into the subsurface and (D) sulfur crystals deposited in the fissures.

than 70 m in the last three decades. We relate the intervals of intense smoke during the afternoon and evening to the enhanced combustion of peat as the stronger winds supply more oxygen through the fissures. The combustion of peat oxidizes the organic carbon, nitrogen, and sulfur and the smoke plumes contain different greenhouse gasses such as CO and CO<sub>2</sub> along with oxides and dioxides of sulfur (SO<sub>2</sub>) and nitrogen (NO<sub>x</sub>). The sulfur crystals deposited along the fissures (Figure 2D) are the result of the condensation of a part of SO<sub>2</sub> in the cooler surface conditions. Both Dommain *et al.* (2014) and Rein (2013) have reported the release of a large amount of greenhouse gasses into the atmosphere from the combustion of peatlands in Indonesia. The combustion of the peat layer present at 200–280 cm depth in Valle del Potosí led to the creation of sub-surface hollows at different places within the basin. The volume reduction associated with the peat burning has caused the subsidence. Higher subsidence (up to 5 m) in some parts of the basin could be either due to the drying and ignition of low carbon containing overlying sediments by the smoldering heat or to the combustion of more peat layers possibly present at deeper levels.

## 5. Remedial measure and recommendation

In Las Tablas de Daimiel national park (Spain), the peat fire was extinguished by transporting water from a nearby river and inundating the basin. In addition, the torrential rains of AD 2009–2010 also flooded the park causing a rise in the water table (Moreno and Jiménez, 2013). However, the replication of a similar mechanism is not possible at Valle del Potosí due to the fact that northern Mexico is arid and there is no major river nearby. The paleoclimatic records from the region show a tendency towards reduced rainfall over the last 2,000 years (Roy *et al.*, 2013, 2014). Similarly, the increasing activity of El Niño Southern Oscillation in the modern era has reduced the amount of rainfall in northern Mexico (Magaña *et al.*, 2003). Nevertheless, similar disasters can be prevented in the near future by prohibiting surface fire and burning activity, sealing off surface fissures and subsurface hollows to prevent air circulation to the subsurface peat layers, and regulating the ground water extraction so that the water table is always maintained





Figure 3. (A) A ~80 cm thick peat layer found at 200 cm depth, (B) sampling of the sediments for chemical analysis, (C) photograph showing the lowering contact of peat with calcareous clay and (D) a burnt tree trunk standing in the basin and next to the village of Catarino Rodríguez.

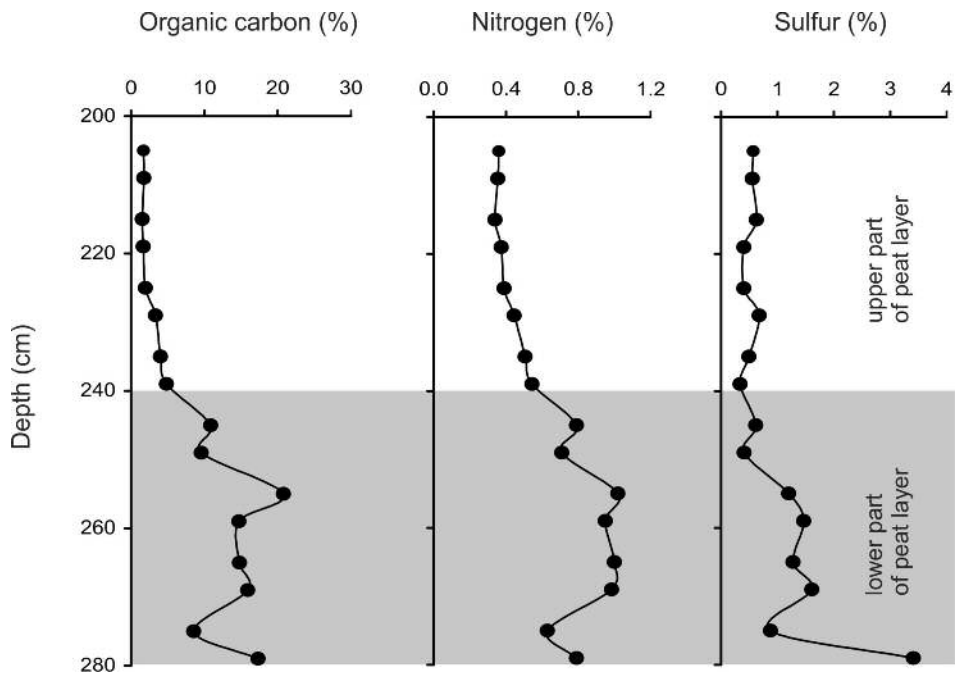


Figure 4. Concentrations of organic carbon, nitrogen, and sulfur (in %) along the peat layer present at 200-280 cm depth.

above the peat layers.

The greenhouse gasses released from the peat fire have an adverse effect on the present day global warming (Rein, 2013). Likewise, the lowering of soil fertility, ground water pollution, and health hazards of local population are reported from different parts of the world (Saharjo *et al.*, 2006; Blake *et al.*, 2009; Prat *et al.*, 2011; Betha *et al.*, 2013; Moreno and Jimenez, 2013). As a consequence, a regional study (at Valle del Potosí and adjacent basins) should also be carried out to identify and document more peat layers in the subsurface. Thus, it is also necessary to undertake a study of health hazards in the local population, possibly caused from airborne fine particulate matter and inhalation of pollutant containing smoke.

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