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# Magnetic gradient map of the mine tailings in Portman Bay (Murcia, Spain) and its contribution to the understanding of the bay infilling process

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ABSTRACT

The present study is a pilot magnetic gradient survey inserted in a set of geological and geophysical works that are planned to understand the infilling process of the Portman Bay (Murcia, Spain).

In a period of 33 years (from 1957 until 1990) the Portman Bay has been silted up with mine tailings. This mining waste, after being discharged into the sea, was transported by littoral currents which sorted it and concentrated the densest mineral fractions (mainly magnetite and other iron oxides). In this sedimentary context, the magnetic gradient map obtained did not detect any massive accumulation of magnetic minerals, but rather a regular distribution following parallel-banded structures in the successive contours of the bay. It has been observed that one of these magnetic bands perfectly superimposes on the ancient coastline visible in aerial photo of 1972, interpreting that this coincidence is explained by the fact that the magnetite was concentrated along the sandy ridges, oriented according to the refraction of the littoral currents.

In this document we analyse the magnetic gradient map obtained in a restricted sector of the Portman Bay. This sector covers an area of 2 ha and it was chosen as a first test. The significant results suggest the suitability of this method to be conducted to the whole bay. The main objective of this study is to show the usefulness of magnetic gradient method to obtain a paleogeographic reconstruction of the infilling process of this bay.



## 1. Introduction

The Portman Bay is located in the La Unión municipality (Murcia, Spain). For 33 years, from 1957 until 1990, it was progressively infilled with mine tailings from a mineral concentration plant situated in this locality. This concentration plant was named Roberto and it was a property of the French mining company Société Miniére et Métallurgique de Peñarroya Espagne (SMMPE).

According to the American Geological Institute (1997) tailings are defined as the refuse material resulting from the concentration, or treatment of ground ore. In this context and following the directives of the authorities based on studies of coastal dynamics the mineral waste from Roberto plant was pumped into the sea via a 2 km long pipeline system which was directed out of the bay, to the west of Punta Galera (Fig. 1). Years later, the progressive infilling of the bay demonstrated how erroneous such studies were.

It is estimated that during this time period, the volume of tailings poured into the sea was around 25 million m$^3$ (Martínez et al., 1993; Oyarzun et al., 2013) corresponding to some 56 million tonnes of mineral waste. An important part of this material, in the order of 5.5 million m$^3$, was introduced into the bay infilling an area of 0.7 km$^2$, while another important part accumulated below sea level outside the bay; in front and along the coastal shelf (Fig. 2).

Due to this exceptional geologic context of the bay and its proximity to the city of Cartagena (about 15 km), in 2012 the Department of Mining, Geological, and Surveying Engineering of the Polytechnic University of Cartagena (UPCT) decided to use the Portman Bay as a test laboratory of geological and geophysical works in order to understand the infilling process of the bay and to obtain 3D models. On the other hand, the Spanish Ministry of Environment and the Spanish Department of Sustainability of the Coast and the Sea are planning a Regeneration Project for the Portman Bay (Oyarzun et al., 2013).

## 2. Geological context. The infilling process of Portman Bay

The mineral waste composition found in Portman Bay is related and close to the mineralogy of the mineral deposits in the Cartagena mountain range (Conesa et al., 2008). In these deposits two different

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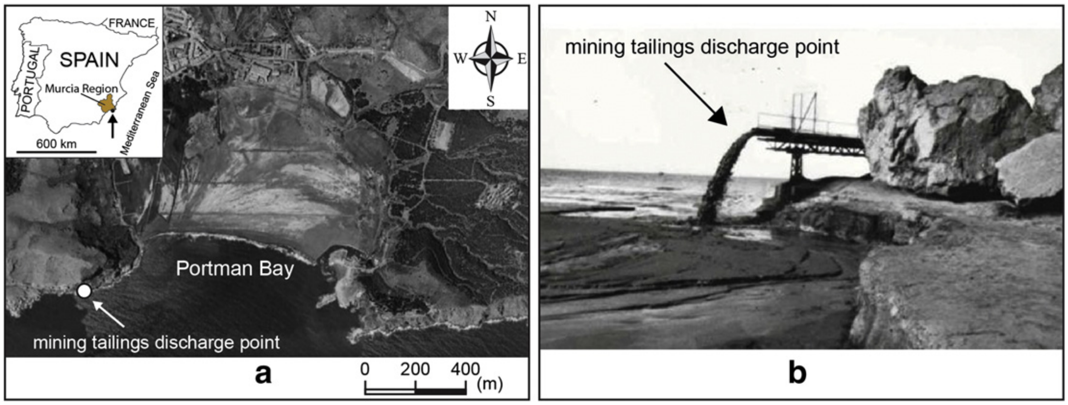


**Fig. 1.** (a) Map of the current location of Portman Bay; a white circle indicates the position of the principal mining tailings discharge point (called Punta Galera). (b) View of the tailings discharge system spouting mining waste to the sea (picture taken during the year 1980).

mineral associations are found: paragenesis 1 (chlorite, sulphides, siderite, and silica) and paragenesis 2 (greenalite, magnetite, sulphides, siderite, and silica) (Manteca and Ovejero, 1992; Oen et al., 1975).

In the Roberto plant, the raw mineral was ground until it had a grain size of $d_{80} < 180$ μm (SMMPE, 1970), and was then passed through flotation circuits where there was differential separation of the sulphides: galena, sphalerite and pyrite. Once the recoverable ores had been separated, the residual pulp or tailings were pumped through a 2 km-long pipeline system to the point where they were poured into the sea, to the west of the bay. From 1959 to 1967, the magnetite was also recovered, but later this practice ceased in order to prioritise the recovery of sulphides (SMMPE, 1970), meaning that the magnetite contained in the raw mineral passed into the residual slurry as a residue.

According to a systematic analysis of the wastes undertaken by the mining company (SMMPE, 1970, 1985), these are principally composed of silica, phyllosilicates and carbonates. Also, they have a significantly high content of heavy metals such as lead (0.2% Pb) and zinc (0.6% Zn); additionally, an important proportion is also made up of pyrite, and iron oxides including magnetite, goethite and haematite.

Following the discharge of waste into the sea, the residues were exposed to wave sea action and littoral currents, which transported and sorted them, both along the length of the coastal shelf and within the bay.

Pauc and Thibault (1976) demonstrated that the littoral currents in Portman Bay vary between summer and winter, in function of the dominant wind regime of the season (Fig. 3). In the summer, with S–SW dominant winds, dextrally rotating drift currents are produced which enter the bay from the southwest and leave to the southeast. In the winter, with S–SE dominant winds, the drift currents are more complex and divide into two branches, one of which rotates in a counter clockwise sense travelling within the bay and returning to the SW while a second branch goes from west to east without penetrating the bay. In the same study Pauc and Thibault (1976) show a map of grain size distribution for 1972, in which it can be seen that the coarsest materials are linked to the coastline while the fine-grained content increases towards the deepest parts of the bay. They conclude that the sedimentary agent controlling the infill is fundamentally the sea waves. As a result, different granulometric fractions are deposited in successive fringes, parallel to the changing beach ridges.

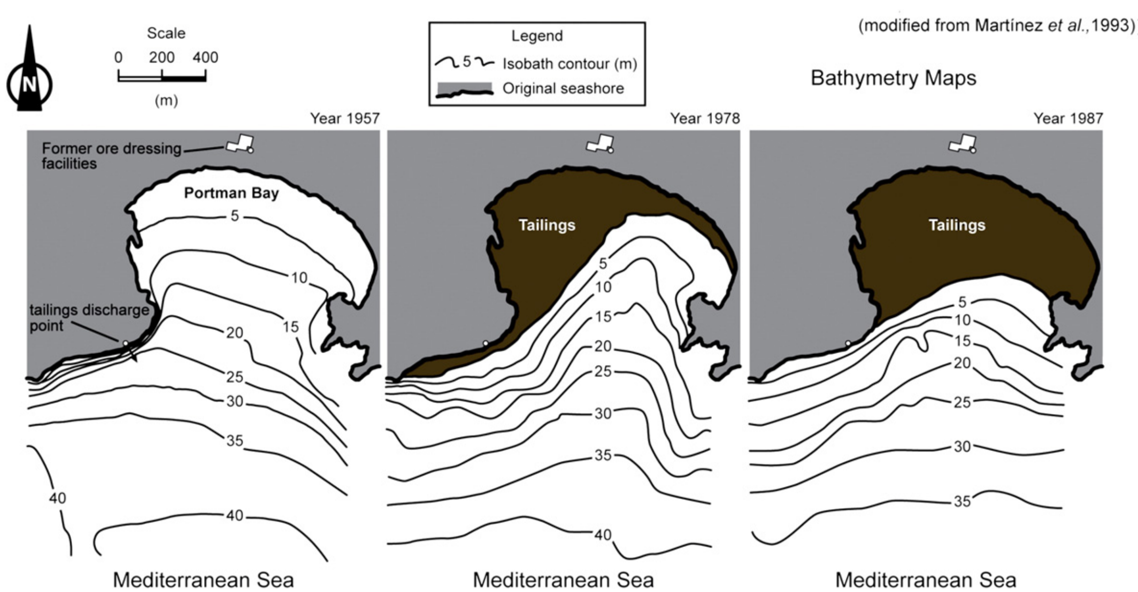


**Fig. 2.** Bathymetric evolution and infilling of Portman Bay.
According to Martínez et al. (1993), adapted for this study.