Magnetic properties as tracers for source-to-sink dispersal of sediments: a case study in the Taiwan Strait

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Modern sedimentation in the Taiwan Strait

The Taiwan Strait is surrounded by Taiwan in the east, the Asian continent in the west, the South China Sea (SCS) in the south and the East China Sea (ECS) in the north (Fig. 1). This relatively narrow and shallow sea regulates water flow between two large marginal seas (i.e., SCS and ECS) and the open Pacific, and receives sediments from the largest land mass (i.e., Asia) as well as a mountainous island with the highest sediment yield in the world (i.e., Taiwan). While circulation pattern in the strait has been well studied in the past 1-2 decades, there has been a lack of progress in understanding sedimentation processes in this all-important gateway for the transport of water and sediments.

A large number (180) of sediment cores and even more (216) surface sediments collected throughout the Taiwan Strait (Figs. 1-2) were analyzed for radionuclides, particle size, clay minerals and magnetic properties to elucidate sedimentation dynamics in the strait. Apparent sediment accumulation rates derived from ^{210}Pb and ^{137}Cs profiles vary from <0.1 to >2 cm/yr, averaging ~0.4 cm/yr and showing a spatial pattern (Fig. 3a) closely related to hydrodynamics and sediment source-to-sink pathways. In conjunction with particle size distribution in surface sediments (Fig. 3b) and the structure of sediment strata revealed by sub-bottom echo images, the radionuclide data can be used to outline three different sediment source-to-sink dispersal systems. Based on sediment loads of surrounding rivers and the distribution of sediment accumulation rates, lateral transport is required to account for the budget and size distribution of sediments in the strait. (Huh et al., 2011).

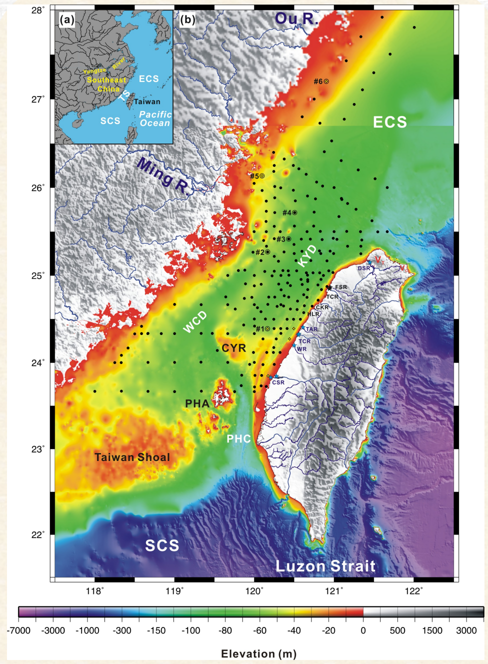

Fig. 1 Map showing (a) the location of the Taiwan Strait (TS) which connects the East China Sea (ECS) and the South China Sea (SCS), (b) sampling sites in the backdrop of the bathymetry of the Taiwan Strait and rivers on both sides of the strait. Major topographic features in the strait are Penghu Channel (PHC), Penghu Archipelago (PHA), Chan-Yuen Rise (CYR), Kuan-Yin Depression (KYD), Wu-Chiu Depression (WCD) and Taiwan Shoal.

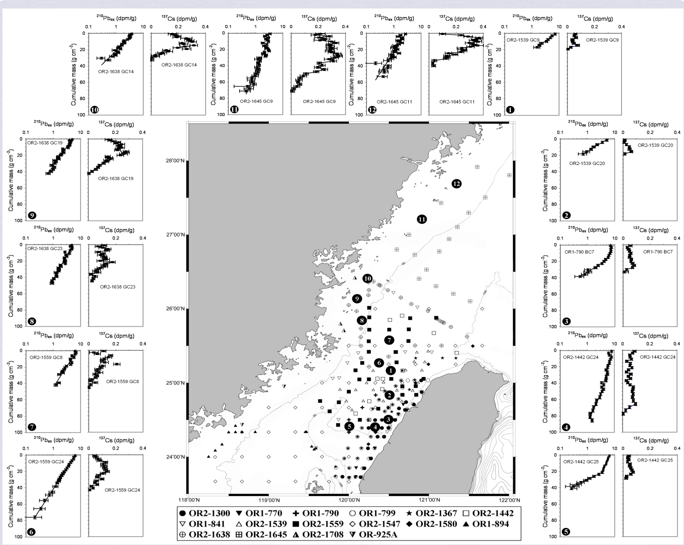

Fig. 2. Sampling sites and profiles of ^{210}Pb and ^{137}Cs in selected cores

Magnetic properties as S2S tracers for sediments

Different lithology between Taiwan and southeastern China leads to diverse mineralogical composition for weathering products derived from the two shores of the Taiwan Strait. The dominant magnetic minerals associated with fluvial sediments from China and western Taiwan are magnetite and pyrrhotite, respectively t (Figs. 3-4). While magnetite commonly co-exists with pyrrhotite in sediments sourced from Taiwan, pyrrhotite is entirely absent in sediments derived from mainland China. Associated with such a distinction are vast differences in magnetic susceptibility (χ), HIRM, SIRM and the S-ratio (Fig. 5), which can be used to study the provenances of sediments in the Taiwan Strait and adjoining marginal seas. Based on any two of these parameters, the magnetic composition of Taiwan Strait sediments can be explained using a two-component mixing model (Fig. 6). Sediment source-to-sink dispersal systems in the Taiwan Strait can then be delineated from the distribution of these parameters. The results not only corroborate the study based on radionuclides and particle size distribution (Huh et al., 2011) but reveal more diagnostic details.

Besides spatial distribution of magnetic parameters in surface sediments, we also analyzed temporal variation of the same parameters in six well-dated cores collected at key sites along the sediment source-to-sink pathways (Fig. 7). From profiles of these parameters in cores from the middle of the northern TS, it is calculated that sediment supply from Taiwan has increased substantially in the past five decades, which may very well be related to accelerated land use and increased frequency of intense rainfalls in Taiwan during the same period.

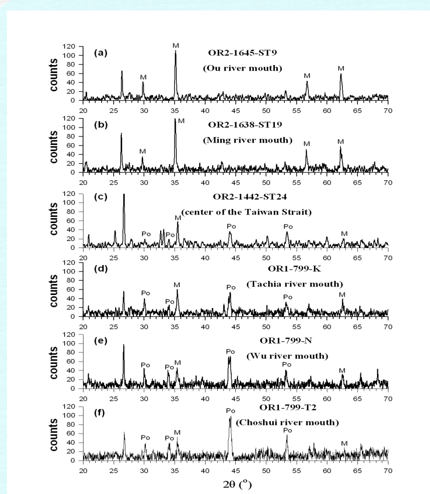

Fig. 3 X-ray diffractograms of magnetic extracts from sediments collected from (a-b) the mouths of the Ou and Ming Rivers in East China; (c) the center of the Taiwan Strait; (d-f) the mouths of the Tachia, Wu and Choshui Rivers in western Taiwan. Magnetite (M) is the dominant magnetic mineral in sediments delivered by the Ou and Ming Rivers whereas pyrrhotite (Po), which has never been found in Chinese rivers, is more abundant than magnetite in Taiwan's fluvial sediments. The locations of the six collected sites are indicated in Figure 1.

Huh et al. (2011) Modern (<100 years) sedimentation in the Taiwan Strait: rates and source-to-sink pathways elucidated from radionuclides and particle size distribution. *Continental Shelf Research 31*, 47-63. doi:10.1016/j.csr.2010.11.002

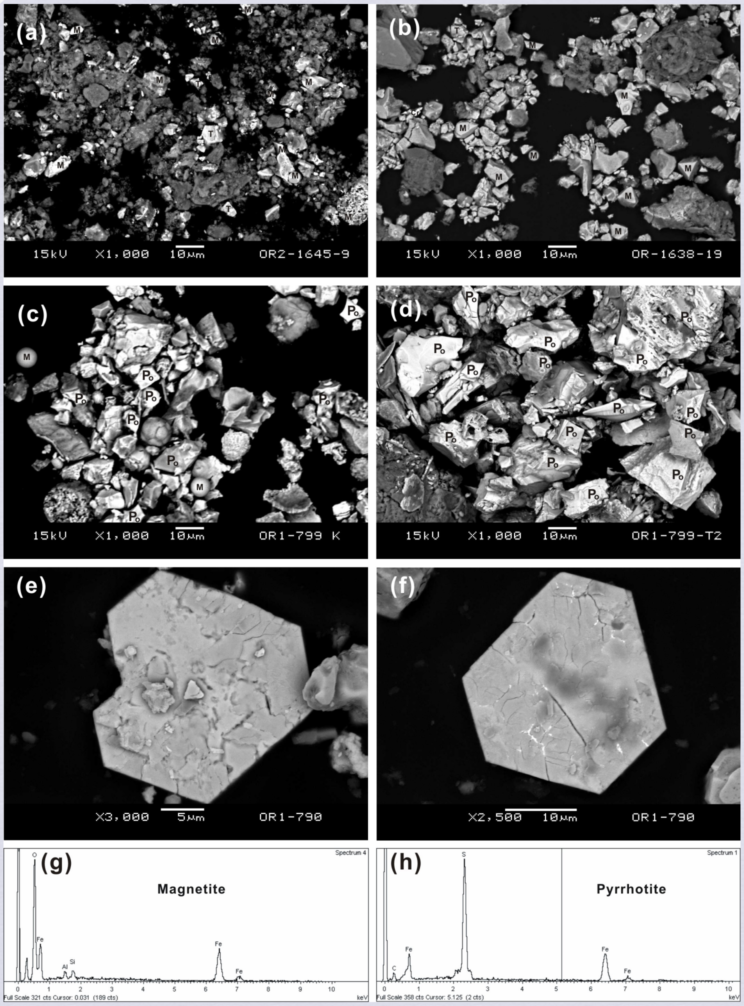

Fig. 4 (a-d) SEM images of magnetic extracts from surface sediments near the mouths of Ou, Ming, Tachia, and Choshui Rivers, respectively. These images are in the same scale (x1000) and show that the grain sizes of magnetite (M) or titanomagnetite (T) from eastern China are smaller than those of pyrrhotite (Po) from western Taiwan. (e-f) Broken and well-formed hexagonal pyrrhotite grains from a sediment core (OR1-790-BC7) at the north of Tachia River's mouth. (g-h) EDS spectra of magnetite and pyrrhotite.

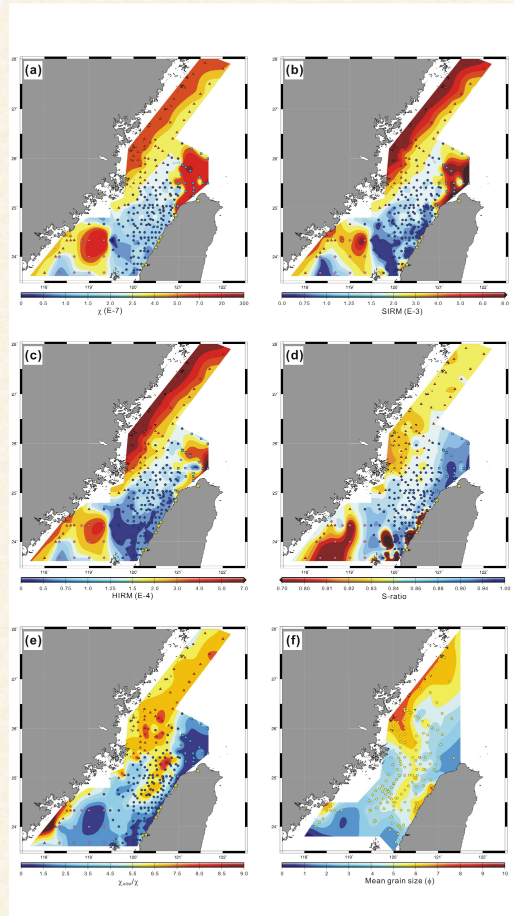

Fig. 5 Spatial distribution of various magnetic properties and mean grain size in surface sediments of the Taiwan Strait: (a) χ, (b) SIRM, (c) HIRM, (d) the S-ratio, (e) the χ_{ARM}/χ ratio, and (f) mean grain size. Different symbols and colors are used to distinguish sediment provenances.

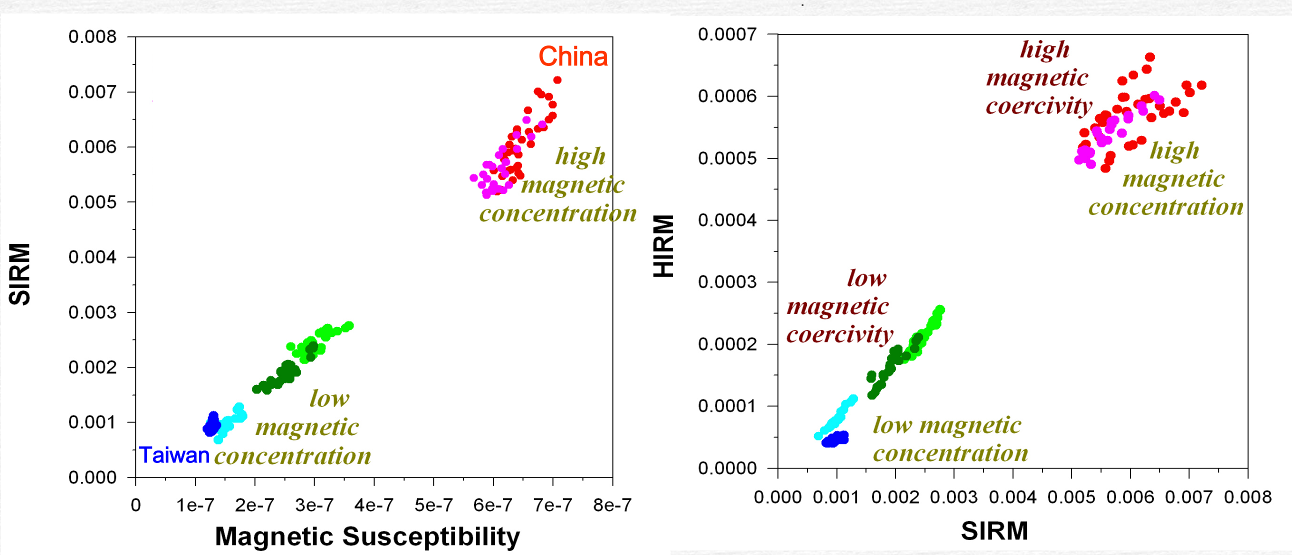

Fig. 6. Correlation between magnetic susceptibility, SIRM and HIRM in Taiwan Strait sediments

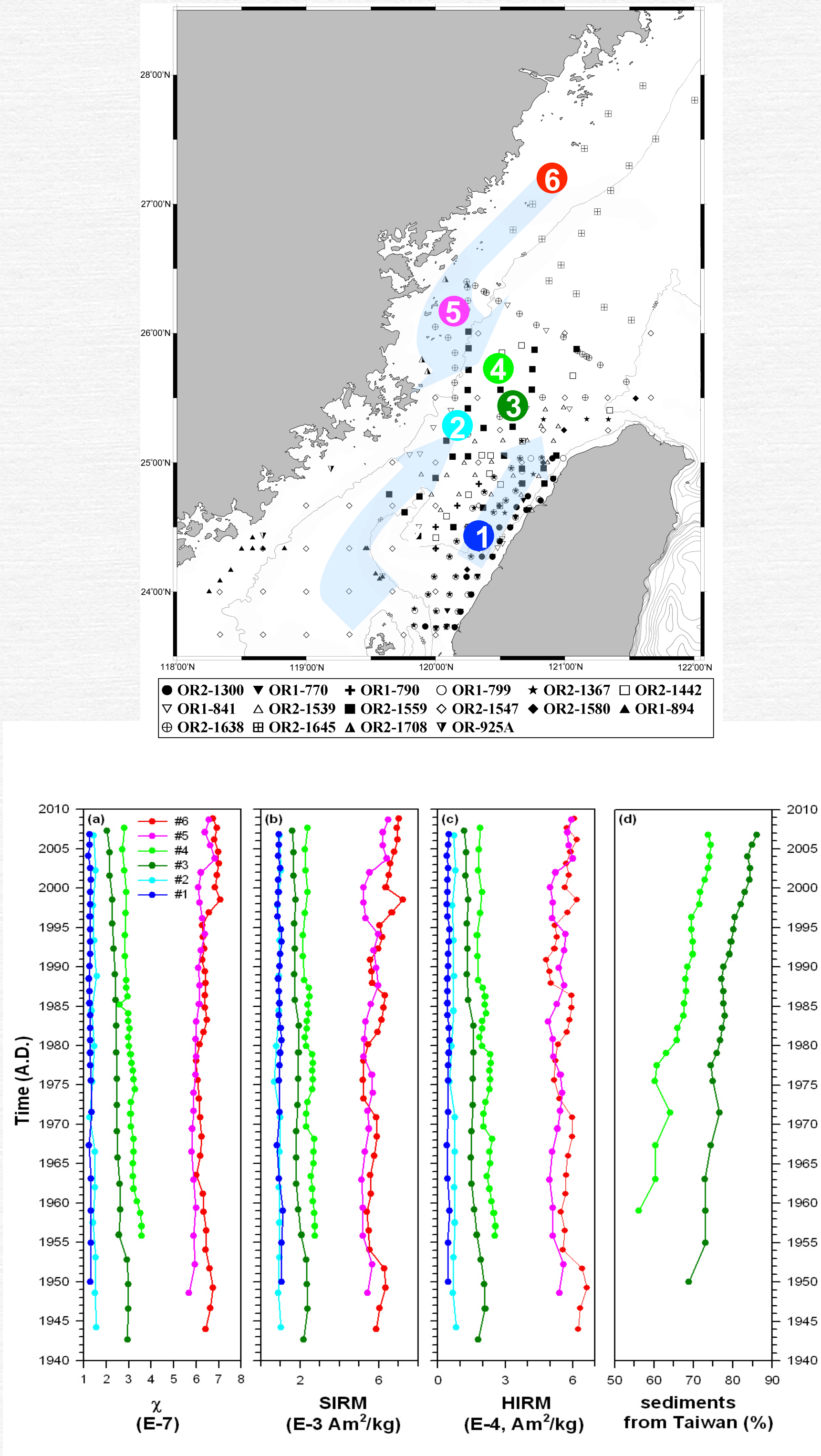

Fig. 7 Locations of 6 well dated cores used to measure downcore variation of magnetic properties of χ, SIRM, and HIRM. The change with time of Taiwan's contribution to sediments deposited in two cores (#3 and #4) in the middle of the Taiwan Strait can be calculated using a two-end member mixing model. Sediment chronology was derived from ^{210}Pb and ^{137}Cs profiles (Huh et al., 2011).