Mineralogical Characteristics of Calcareous, Gypsiferous and Saline Materials of Arid Soils (Hormozgan Province, Southern Iran)

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INTRODUCTION

In order to address society's needs related to soil resources, it is important to understand the landscape distribution of soil minerals and the processes responsible for their occurrence. Soil minerals can be used to help understanding soil pedogenesis (Graham and Geen, 2010), the current behaviour of arid lands (Reid et al., 1993) and to interpreting paleoenvironmental conditions (Khormali et al., 2003).

Mineralogical composition of the bulk soil, rock and various grain size fractions, are the important factors for soil formation, which are dealt with a detail and contribute to the distinction of provenance. The contribution of bedrock types to soil clay mineralogy is dependent on the intensity of weathering, which differs from one environment to another, and factors like relief, climate and vegetation. Thus, different bedrocks react differently to chemical weathering, resulting in various landscapes and weathering products (Sultan, 2006).

The purposes of this study are to compare the mineralogy of sedimentary rocks with the soils to establish the contribution made by sedimentary material to arid soils developed on evaporites and alluvium materials and, investigate mineralogy of different grain size particles (sand, silt, and clay) to assess the provenance and resultant factors on distribution and types of minerals.

MATERIALS AND METHODS

Study Area and Geological Setting

The target area (Hormozgan Province, Southern Iran) is located in a desert to a semi-desert like region with a warm (hot) and dry climate (Fig 1). The soil temperature regime is hyperthermic but some rare north and coastal areas have thermic and isothermic regime, respectively. Aridic and Ustic soil moisture regimes were obtained for the whole Hormozgan province.

The study area dominated with diverse lithostratigraphic units from Late Precambrian to Cenozoic sequences and covered by Carbonatic sequence of Jurassic–Cretaceous age, evaporate formations of Eocene to Pliocene age and Quaternary deposits. Stable subsidence and the unique landscape–climatic conditions favoured the accumulation of a very thick sedimentary lens of carbonate rocks and evaporates (Aghanabati, 2004).

Laboratory Analyses

Soil samples from different 28 soil pedons and corresponding sedimentary parent rocks (n=16) were selected for the study. Soil properties and constituents analyzed include: particle size distribution, organic matter, cation exchange capacity (CEC), percentage of gypsum, calcium carbonate equivalent (CCE), electrical conductivity (EC) and pH in saturated paste extracted according to Methods of Analysis for soils in Arid and Semi-Arid Regions Handbook (Bashour & Sayegh, 2007).

Four treatments (heating to 550ºC; solvation with Glycerol; solvation with Dimethyl Sulfoxide) were prepared for distinguishing different clay minerals in oriented samples (Moore and Reynolds, 1997). The samples (random powder, oriented aggregate) for mineralogical analysis were scanned using an X-ray diffractometer (Philips PW-1710 CuKα radiation). Thin sections of rocks were studied under normal and circular polarized light with petrographic microscope.

Principal Component Analysis (PCA) was used on the dataset in order to reveal possible relationships between soil properties. Statistical analyses were performed with the MS Excel application XLstat and SPSS 17.0. A probability level of $p \leq 0.05$ was chosen to establish statistical significance. Prior to the multivariate analysis, variables were fitted to normal distributions and all data were scaled to unit variance and mean centered.

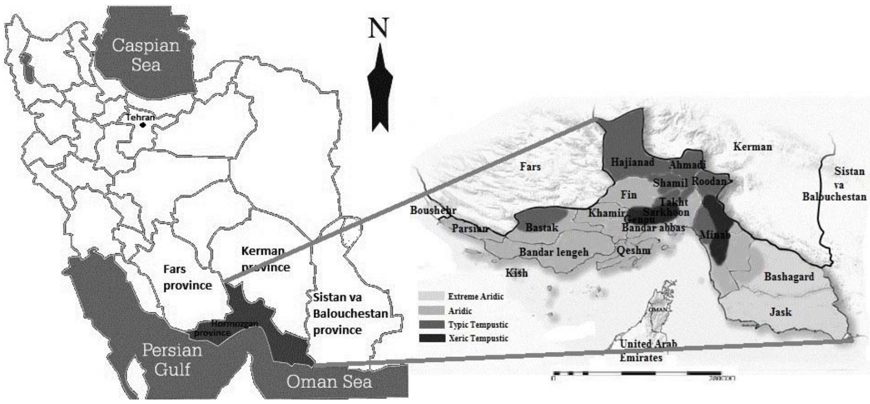

fig 1. Location of Hormozgan province in Iran map and soil moisture regime map.

palabras clave: Mineralogía de suelos, Área fuente, Distribución granulométrica, Desarrollo de suelos

key words: Soil mineralogy, provenance, particle size distribution, Soil development

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RESULTS AND DISCUSSION

The maximum, minimum, mean, and standard deviation of soil physicochemical characteristics of the studied soil samples are given in Table 1. Soils are generally alkaline in nature and high in soluble salts and carbonates. Characteristically these soils are very low in organic matter/humus. The surface gravel is common in most regions.

Soil parameters	Minimum	Maximum	Mean ±SD*
Sand (%)	12.50	90.00	53.58 ±20.27
Silt (%)	8.00	82.00	41.02 ±18.71
Clay (%)	1.00	18.00	5.68 ±4.11
pH	7.10	8.70	7.85 ±0.37
EC (dSm^{-1})	0.02	45.00	9.87 ±12.79
SAR	0.01	14.36	1.34 ±2.30
CEC ($cmolckg^{-1}$)	2.15	19.00	7.91 ±3.50
CCE (%)	21.10	81.53	47.92 ±16.48
Gypsum (%)	0.08	29.03	7.08 ±9.18
OM (%)	0.2	1.80	0.70 ±0.37

*Table 1. Statistical summary of soil physicochemical properties *SD: Standard Deviation*

According to Soil Taxonomy (Soil Survey Staff, 2010), soils were classified as Aridisols, Entisols and Inceptisols with calcic, gypsic, salic, cambic, argilic horizons and ochric epipedon.

The sand and silt fractions of these soils have mixed mineralogy i.e. silt is composed of quartz, calcite, alkali feldspars, plagioclase, dolomite, 14Å-phyllosilicates (chlorite) and mica minerals while sand fraction has gypsum in addition to the minerals present in silt. The main minerals in silt and sand fraction are quartz and alkali-feldspars and in the all analyzed soil samples calcite and dolomite are present. The clay fraction (< 2 μm) of soil and rock samples exhibit illite, chlorite and palygorskite throughout in most pedons (Fig. 2).

Vermiculite was absent while kaolinite were present though in minor amounts in rare series. The clay mineralogy results revealed that detrital input and inheritance is possibly the main source of kaolinite, smectite, chlorite and illite, while in situ neoformation during the Tertiary shallow saline and alkaline environment could be the dominant cause of palygorskite occurrences in the sedimentary rocks (Khormali et al., 2003).

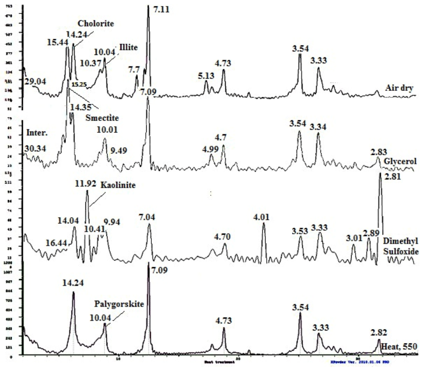

fig 2. X-ray diffractograms of the clay fraction

In arid homogeneous climate of southern Iran, where sedimentary covering is sparse and lithological variability pronounced, parent rock has a significant role on mineral distribution.

PCA was used to assess the dominant component in the different parameters and to make a synthesis of the relationship between physicochemical parameters and soil mineralogy (Fig. 3). Quartz, alkali feldspars, calcite minerals, gypsum presence, Cation Exchange Capacity, sand, and silt percent are dominant factors which determining the characteristics and soil developments of arid soils of Hormozgan Province.

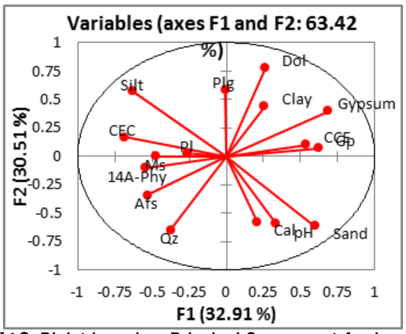

fig 3. Biplot based on Principal Component Analyses of soil physicochemical properties and soil mineralogy.

The PCA results (Fig. 3) showed that positive PC1 is dominated by sand, CCE, and gypsum and negative PC1 is dominated by 14A-phy, Afs, silt, and CEC. The positive PC2 contains mainly silt, Plg, Dol, while negative PC2 contains Qz. It can be concluded soils are naturally gypsiferous and calcareous with light textures. Amount of silt, Palygorskite and dolomite are affected by pedogenesis process, while quartz follow a different trend in soils rather than other minerals.

Abundance of kaolinite in marine sediments suggests a warm and humid climate with high rainfall in the Tethys region during the early Palaeocene. Gradually kaolinite disappearance giving way to palygorskite, is suggesting the progressive development of arid climatic conditions in parts of the Tethys from the late Palaeocene to the early Eocene that have continued to the current periods. In most carbonatic rocks of Zagros setting, neomorphism of carbonate mud (micrite) to sparry carbonate (sparite) cement demonstrated moving toward a more pacific, warmer, and shallower environment.

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