Geoderma Regional 7 (2016) 49–58

Contents lists available at ScienceDirect

Geoderma Regional

journal homepage: www.elsevier.com/locate/geodrs

The role of pedogenic overprinting in the obliteration of parent material in some polygenetic landscapes of Sicily (Italy)

Riccardo Scalenghe [a,c,*], Claudio Territo [a,b,c], Sabine Petit [c], Fabio Terribile [d], Dominique Righi [c,1]

[a] Università degli Studi di Palermo, Palermo, Italy
[b] Ministero delle Politiche Agricole, Alimentari e Forestali, Roma, Italy
[c] CNRS/Université de Poitiers, Poitiers, France
[d] Università degli Studi di Napoli Federico II, Portici, Italy

ARTICLE INFO

Article history:
Received 9 October 2015
Received in revised form 22 January 2016
Accepted 25 January 2016
Available online 29 January 2016

Keywords:
Gypsic Vertisol
Vertic Cambisol
Gypsic Haploxerept
Vertic Haploxerept
Micromorphology
Clay
Mediterranean

ABSTRACT

Many soils older than the Holocene have experienced several changes, and possess properties that may be due to the complex effect of several stages of soil development; these soils are called polygenetic. It is still rather unclear, however, if, as time elapses, pedogenic processes tend to diverge generating different soils, or converge towards increasingly similar soils. We studied five pedons (37°60′N, 13°90′E) exposed to present weathering simultaneously since the Holocene but located on Upper Miocene or Holocene parent material. Their XRD and FTIR clay mineralogy reveal an overall homogeneity; smectites, calcite and gypsum reach the thermodynamic equilibrium, a slight undersaturation of the illitic phase occurs in all soil profiles. Also soil micromorphology confirms a general similarity: vertic features detected as anisotropic lines and aureoles occur in all soils. Net mass chemical fluxes, based on mean translocation values per profile, excluded vertical (depth to the soil profile) and horizontal (topographical positions of profiles) pedogenic domains. Here, we show that the elapsed time of weathering has obliterated the effects of past sea transgression, revealing the vertic character independently on the age of its parent material in the case of soils that develop from Holocene, Messinian and Tortonian deposits, with a rate of pedogenesis plausibly in the order of 1/10 mm per year. The soils of today reveal a strong homogeneity, in particular, in the mineralogical composition of the very fine earth; twenty-five per cent kaolinite and 75% interstratified illite/smectite are independently inherited from the parent material and are thermodynamically very stable. Vertic properties here could be considered to be in a steady-state condition nevertheless they experienced significant environmental disturbance.

1. Introduction

Is it true that the degree of weathering reflects the age of soils? Is there any relationship between the degree of pedogenic development and self-organisation? It depends (FitzPatrick, 2006; Targulian and Krasilnikov, 2007). For instance, Yoo and Mudd (2008) found that mineral residence times were significantly shorter than soil age. However, most soils are not developed by a single set of processes, but undergo polygenesis, inheriting (Nordt et al., 2004) or obliterating (Chesworth, 1973) some features with each wave of pedogenesis by overprinting under the seasonal alternation of wet and dry cycles, which enables the hydrolytic weathering of the most reactive soil particles: clay minerals. The quantitative approach, in which gains, losses, transfers and transformations of soil components, interpreted via chemical mass-balances (Ugolini et al., 1977; Chadwick et al., 1990; Brimhall et al., 1991; Jersak et al., 1995) or the in situ solution chemistry approach, pioneered by Ugolini and Dahlgren (1987), have enhanced our understanding of soil-forming processes (Bockheim and Gennadiyev, 2000).

In the Mediterranean region, pedoenvironments reveal analogous traits (Fig. 1a): specific climate, surrounding mountains, dust from the desert (Yaalon, 1997), anthropogenic influence throughout millennia, and accumulation of secondary calcium carbonate or more soluble salts (Peña and Torrent, 1990; Bilsel, 2004). In the Mediterranean region, Cambisols (mainly calcaric) dominate, followed by Leptosols, Luvisols, Regosols and Fluvisols (IUSS WG WRB, 2015): Eutric soils and calcareous parent materials and soils are most representative in this territory, and are related to the marine sediments that have been deposited (Ibáñez et al., 2013). These soils began their anthropisation more than two millennia ago with massive deforestation resulting in dramatic erosive processes at yields up to 200 tons km^{-2} yr^{-1} (Yaalon, 1997), and irrigation resulting in salinization.

Simplifying the context, two main types of soils are representative: rubeficated soils rich in haematite and ferrihydrite and darkened soils rich in phyllosilicates (Torrent, 1995). Calcareous and low in quartz parent material favour the formation of dark soils (Srivastava et al., 2002), Vertisols, that develop in the consequence of shrinking/swelling of

* Corresponding author at: Università degli Studi di Palermo, Palermo, Italy.
E-mail address: riccardo.scalenghe@unipa.it (R. Scalenghe).
[1] La Rochelle 19/01/1943 – Poitiers 07/03/2010.

http://dx.doi.org/10.1016/j.geodrs.2016.01.003
2352-0094/

plastic soil materials and argillipedoturbation (Mermut et al., 1996; Miller et al., 2010; Wilding and Tessier, 1988; Williams et al., 1996). These soils lack in clear horizon differentiation that results from high clay content with predominance of 2:1 type expanding minerals, and develop on a wide range of parent material (Barbiero et al., 2005, 2010; Brierley et al., 2011; Driese et al., 2016; Mermut et al., 1996; Nordt et al., 2004). It is normally taken for granted that Vertisols occur in areas with gentle slopes, mostly confined to landscapes with slopes <10% (Simonson, 1954), and lacking an integrated drainage network, which normally results in surface ponding (Mermut et al., 1996); while they are normally largely absent in hilly areas. One still debated existing knowledge gap is to know if Vertisols represent intermediate stages of soil development on the genetic pathway to another soil order or if Vertisols are stable and persistent. Their stability is considered due to dominantly low slope gradients (Buol et al., 2011).

As Bockheim and Gennadiyev (2000) pointed out, many pedologists prefer to use generalised processes, such as additions, removals, translocations, and transformation, instead of specific soil-forming processes (e.g., vertisolisation, argilluviation), claiming that these processes are merely illustrative. However, a few years later, Bockheim and Gennadiyev (2009) summarised descriptive models of these processes and showed that they exist in reality. The experimental approaches described herein show that these processes can be studied as natural phenomena in the laboratory and field. We have tried to confirm these accounts by parallel approaches applied to a specific case study of vertisolisation. Here, our results are discussed in terms of how prolonged periods could smooth the imprints of different parent materials. The aim of this paper is to understand if vertic properties are stable and persistent in a hilly landscape, secondarily if factor time of pedogenesis could obliterate the changes due to the sequence of cycles of sea transgression–regression.

2. Regional setting

In the centre of the Mediterranean Sea (Fig. 1a), the evaporitic deposits of Sicily, a Lower Gypsum Unit followed by the Halite Unit and the Upper Gypsum Unit, comprise an area larger than 1000 km^2. In the central part of the Caltanissetta Basin, the succession of these deposits is interspersed with older deep-water deposits of the Tortonian/Messinian age (Decima et al., 1988). These pre-evaporitic deposits containing clays and marly clays with sandy intercalations. Chronologically, Messinian stages could be subdivided into the i) pre-evaporitic phase (7.2–6.0 Ma), ii) lower evaporites (6.0–5.6 Ma) and iii) post-evaporitic phase *Lago-Mare* deposits (5.6–5.3 Ma) (Krijgsman et al., 1999).

We studied a slope (Mustigarufi, 37°60′N, 13°90′E; MAT 17.8 °C, MAP 460 mm) where soils have developed from Holocene (~12 ka BP), Messinian (>5.3 Ma) and Tortonian (>7.2 Ma) deposits (Fig. 1b_1). The oldest outcrop belong to Tortonian Terravecchia Fm. (clays, sands and conglomerates) below Messinian Gessoso-Solfifera Fm. (diatomitic marls, limestone and dolomitic limestone, gypsum and halite and potash salts) deposits, the younger to Holocenic deposits, conglomerate and sands alluvial deposits and a clayey, marly-clayey and silty dolina (Dazzi and Monteleone, 2002). In particular, from the bottom of the slope pedon P1, P64 and P22 were located on Upper Miocene parent material, while pedons P3 and P4 on Holocene parent material (more details in Supplementary Information). All deposits have been exposed to present weathering simultaneously since the Holocene (Bellanca and Neri, 1993; Dazzi and Monteleone, 2002; Laudicina et al., 2013). In this environment, multiple land use changes have occurred; probably the most important of which is the succession of forestry–agriculture–forestry. In fact, most of the Mediterranean region was covered by forests when deforestation began with the early introduction of agriculture. It was strongly accelerated during the Greek and Roman ages, and the clear-cutting of forests had a profound impact on soil properties (Hajabbasi et al., 1997; Tinner et al., 2009; Tzedakis, 2007). Mustigarufi was re-forested in 1960 by planting stocks of eucalyptus for harvesting as lumber. The present vegetation is rather homogeneous; it consists of stands of *Eucalyptus camaldulensis* and *E. occidentalis*, while scarcer are *Pinus halepensis*, *P. pinea* and *Cupressus sempervirens* (Scalenghe et al., 2015). This homogeneity contrasts with the variability of the soil properties in the same area (Fig. 1b_2).

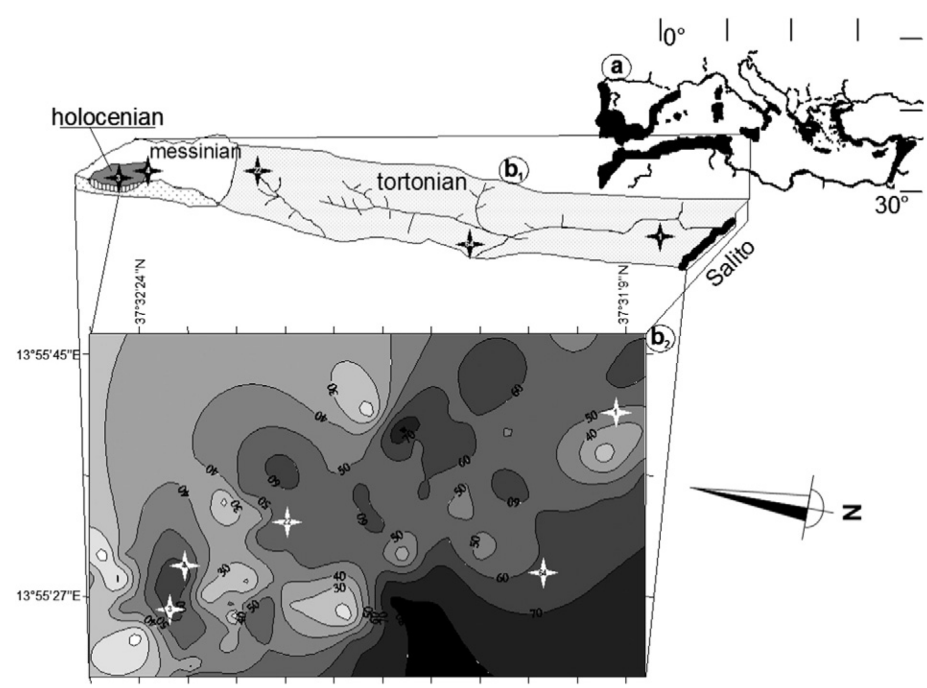

Fig. 1. (a) Soils developed under Mediterranean climates between the latitudes 30° and 40°N (after Yaalon, 1997); (b_1) The 200 ha-clayey hillslope in Sicily (37°60′N, 13°90′E) where soils have developed over Holocene (~12 ky BP), Messinian (>5.3 My) and Tortonian (>7.2 My) deposits (after Laudicina et al., 2013); (b_2) Kriged clay content is given as a percentage of the fine earth of the topsoil (n = 94). Selected profiles are identified by crosses in both schemes. Scales of sketch b_1 are arbitraries.