Geoderma Regional 7 (2016) 323–329

Contents lists available at ScienceDirect

Geoderma Regional

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

Palaeosol nomenclature and classification for South Africa: A new perspective

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ARTICLE INFO

Article history:
Received 22 March 2016
Received in revised form 23 June 2016
Accepted 24 June 2016
Available online 26 June 2016

Keywords:
Calsisols
Langebaanweg
ISRIC-IUSS WRB
Palaeopedology
Soil Taxonomy

ABSTRACT

Despite being well renowned for prominent palaeosols, there is no documented attempt at appraising the suitability of existing palaeosol nomenclature and classification systems for palaeosols from South Africa, even in the wake of increasing scientific awareness of the applicability of palaeosol-based proxies for palaeoenvironmental and palaeoclimatic reconstructions. In this study, selected palaeosols from five prominent sites in South Africa were classified using the landmark system of Mack et al. (1993) and the most recent classification system proposed by Krasilinikov and Calderón (2006). Sequel to field identification and description of the diagnostic horizons, the palaeosols were analysed using routine laboratory procedures for properties including particle size distribution, pH, calcium carbonate content, colour, elemental geochemistry, clay mineralogy and micromorphology for detailed characterisation and classification. The palaeosols qualified as ferric Calsisols, calcic Gleysol, concretionary Argillisol, ochric Calsisol and ochric Protosol using Mack et al. system; and Infracalsisol, Infraluvisol, Infraplinthisol and Infracambisol by Krasilinikov and Calderón system. Plinthite was quite prominent in the red palaeosol. We, therefore, suggest that another term be coined in the two systems to take care of palaeosols with outstanding preserved plinthic horizons. The complex nature of palaeosols and after burial alterations brings about a lot of changes which would have to be addressed by the international palaeopedology community in order to enhance communication and exchange of knowledge and formulation of relevant theories amongst scientists. Future studies of palaeosol classification in the region would benefit from a more robust and improved unified global classification scheme which would address the loopholes of the existing systems.

1. Introduction

Palaeosol is soil that formed on a landscape of the geological past. It carries the imprints of the pedogenic factors that are no longer operational in the present. In some cases, palaeosols could be found not preserved as complete and undisturbed profiles but features such as truncations, stone lines and superimposed allochtonous materials on genetic horizons can detect such discontinuities (Fedoroff et al., 2010; Eze and Meadows 2014a). Palaeosols are commonly classified into three major types on the basis of their position in a stratigraphic section and in the landscape namely buried, relict and exhumed soils (Birkeland, 1999). Buried soils are those which were not affected by later pedogenesis since the time they formed because they got buried by younger sediments. Non-buried or relict soils are at the land surface since the time of their initial formation and they may or may not have acquired their properties sometime in the past whereas exhumed soils were formerly buried but then exposed to current pedogenesis. Modern soil is, on the other hand, will be used in this manuscript to mean soils having properties from the presently operational soil-forming factors.

In principle, classification is an orderly way of grouping objects based on similarity of observable and/or measurable attributes, thereby improving systemisation of knowledge and enhancing communication. Classification opens new lines of research and allows for exchange of knowledge amongst stake holders. Unlike other fields of the Earth sciences including pedology, sedimentology, palaeontology, etc. which have well organised and, in some cases, universally accepted systems of classification, palaeopedology is still struggling in this area, as compared to its other aspects (Imbellone, 2011). Although there are numerous classification systems available for modern soils, the major topical challenge of palaeopedology has been the development and adoption of a unified classification system for palaeosols across the globe. Palaeopedologists strongly emphasize the need to not use classification schemes designed for modern soils for palaeosols for the following reasons: i) these systems do not focus on the limitations of palaeosols since they are not directly the object of study. For example, the definition of soils by Soil Survey Staff (1999) as "natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that are distinguishable from the initial

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http://dx.doi.org/10.1016/j.geodrs.2016.06.004
2352-0094/

material as a result of additions, losses, transfers, and transformations of energy and matter or the ability to support rooted plants in a natural environment" lends more credence to this; ii) higher order categories of modern classification uses climate information and this cannot be obtained from palaeoclimate models for palaeosols either for a palaeo geological unit or time frame (Imbellone, 2011).

Since there is no documented study aimed at reviewing or providing palaeosol classification systems in South Africa, palaeosol nomenclature has been incongruous. For example, Smith (1990) classified alluvial palaeosols of the Permian lower Beaufort in the south western Karoo basins after USDA *Soil Taxonomy* – a system much criticised since it takes climatic parameters into consideration, specifically Aridisols and Gelisols at the order level. The major limitation associated with IUSS-WRB, USDA *Soil Taxonomy* and South Africa Soil Classification System is that they are based on a large number of modern diagnostic soil properties such as cation exchange capacity (CEC), moisture content, organic matter content, bulk density, pH, base saturation, argillic horizons, thickness of horizons and compaction that are not, in all cases, preserved in palaeosols (Yaalon, 1971; Retallack 2001). In palaeosols, estimation of surface diagenetically altered horizons would be near impossible due to loss of organic matter by erosion and decomposition.

Several approaches have been applied globally for classification of soils and palaeosols, but none is generally endorsed by the palaeopedology community due to the inherent shortfalls in their formation concepts and definitions. In South Africa, the three most popular systems of modern soil classification systems include: World Reference Base (WRB-ISRIC-IUSS, 1998), USDA *Soil Taxonomy* (1999) and South African Soil Classification System (SCWG, 1991). The ISRIC-IUSS WRB system is used more internationally and, unlike USDA *Soil Taxonomy*, does not explicitly utilise climatic information in its classification. Since the works of Land Type Survey of South Africa and Van der Merwe (1940) – the all-inclusive accounts of soils of South Africa - soil classification has evolved remarkably in the country leading to the development of a South African Soil Classification System (SCWG, 1991). The South African soil classification system has two hierarchical elements: form and family to date, 73 forms and 400 families have been identified. To further improve communication via effective classification, Fey (2010) created and mapped these soils into 14 groups based on identification of diagnostic horizons as defined by the South Africa Soil Classification Working Group (1991). ISRIC-IUSS WRB and South African soil groups therefore have something in common – they both use modern diagnostic horizons and properties in their classification. Correlation with ISRIC-IUSS WRB proves that 25 out of 32 reference groups are present and represented in the 14 South African soil groups (Fey, 2010).

Notable classification systems developed for palaeosols include: i) the classification of Duchaufour (1982) which lays emphasis on pedogenic processes operating under certain environmental conditions rather than properties, a particular attribute that makes it suitable for both modern soils and palaeosols; ii) the landmark palaeosol-specific taxonomy of Mack et al. (1993). It is a hierarchical system that draws fundamentally from six observable pedogenic features or processes: organic matter content, horizonation, redox conditions, in situ mineral alteration, illuviation of insoluble minerals and accumulation of soluble minerals. The major drawback of this system as argued by Retallack (1993) is that since it is specifically meant for palaeosols, it could weaken communication between palaeopedologists and soil scientists. Other systems include those by Nettleton et al. (1998), later modified in Nettleton et al. (2000), Retallack (2001) and a recent system proposed by Krasilnikov and Calderon (2006). A very comprehensive review of the strengths and weaknesses of these systems is extensively presented in the work of Imbellone (2011).

There has been increasing awareness especially in the last decade about the reliability of palaeosol-based proxies for palaeoenvironmental and palaeoclimatic reconstruction (Retallack, 2014). In South Africa, palaeosols have been studied for inferences of palaeoclimates and palaeoenvironments (e.g. Botha and Fedoroff, 1995; Watanabe et al., 2000; Eze, 2013). Climate variables spanning precipitation, temperature and palaeo pCO_2 composition have been successfully reconstructed using palaeosol based proxies. It is against this backdrop that the need for a unified palaeosol classification system has become pressing so as to facilitate communication amongst scientists, in the same way as the universally-adopted binomial Linnaean system of plants and animal taxonomy works. In South Africa, however, there has been no previous attempt at classifying palaeosols despite their being widely distributed and that it is the locus of one of the world's oldest palaeosols (2.6 Gb ya) (Watanabe et al., 2000), being a cradle of humankind and single largest fossil hominin in Africa (McCarthy and Rubidge, 2013; Berger et al., 2015). In this paper, classification of selected palaeosols from five locations in South Africa using the well-known system proposed by Mack et al. (1993) and a recent system of Krasilnikov and Calderon (2006) were evaluated for their suitability. The study further highlights the need for a universal classification and nomenclature system for palaeosols.

2. Geographical and geological setting

Five palaeosol profiles were described, viz two at Langebaanweg Fossil Park (LBW) and one each at Koeberg, Glenhof road at the Cape Peninsula and Goukamma (Fig. 1). The Fossil Park is located approximately 120 km north of Cape Town and the exposed palaeosol profile is situated at latitude 32°57.784″ S and longitude 18°06.367″ E approximately 30 m above sea level. The local geology of LBW comprises Late Neogene Varswater formation (Fm) of the Sandveld group overlain by the Springfontyn Formation and calcareous aeolian deposit of the Langebaan formation (Fm) and Varswater formation (Roberts et al., 2011).

The exposed palaeosol at Koeberg is in a coastal cliff which lies north of Cape Town on the west coast at 33°37′15.0″ S and 18°23′27.0″ E, some 200 m northwest of the Koeberg nuclear power plant. Koeberg lies within the so-called winter rainfall zone (Chase and Meadows 2007) and today receives around 372 mm precipitation annually.

The palaeosol at Glenhof road represents a soil-geomorphic unit and is located near the foot of the iconic Devil's Peak (a prominent projection of the Table Mountain), formed of Palaeozoic Cape Supergroup rock. The amount and spatial distribution of rainfall in the region is strongly variable and strongly influenced by topography, although the mean annual precipitation and temperature for the location are 1300 mm and 17.3 °C respectively (Harris et al., 2010). The site is underlain at depth by deeply weathered meta-sedimentary strata of the Neoproterozoic Tygerberg Formation of the Malmesbury Group. The meta-sedimentary strata originally comprised deep water marine mudrock and are mantled by relatively thin deposits composed of alluvial river terrace material (Kantey and Templer Pty, 2008).

The palaeosol section at Goukamma Nature Reserve is exposed on the seaward side of a dune barrier a few kilometres east of Sedgefield between 34°02′48″ S, 22°50′20″ E and 34°02′53″ S, 22°50′43″ E. Goukamma receives precipitation all year round from a combination of both winter cyclonic and tropical easterly flow activity (Weather Bureau, 1986). Both Koeberg and Goukamma are underlain by strata of established aeolian sedimentary patterns which were established in the Late Tertiary and persisted into the Quaternary (Roberts et al., 2009, Bateman et al., 2011).

3. Materials and methods

3.1. Field sampling

Undisturbed hand samples were then taken from each horizon of the palaeosol profiles. These samples were specifically marked for thin section preparation. More representative samples were also collected and bagged for further laboratory investigations. In the field, colour

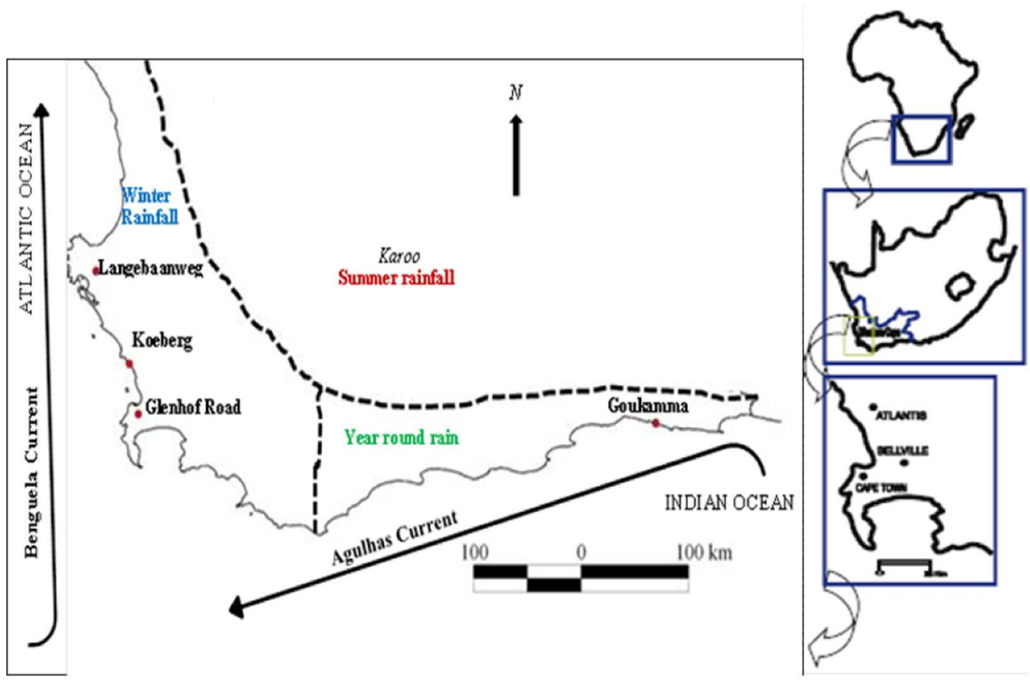

Fig. 1. Map showing the location of the studied palaeosols.

was described using the Munsel soil colour system (Munsel Color Company, 2000), while the general macromorphological properties were described in accordance with the guidelines for soil profile description (FAO, 2006).

3.2. Laboratory methods

Pre-treatment of samples included gently grinding to break up clods and subsequently passing it through a 2 mm sieve to separate gravel and roots/rhizomes from the 2 mm soil fraction. Dry and moist colours were determined using Munsell colour chart. Particle size distribution was determined by hydrometer method (Bouyoucos, 1962). Both soil pH and electrical conductivity (EC) were measured with pH and electrical conductivity meters respectively in a 1:2.5 (soil to solution) ratio. For micromorphological analyses, oriented samples were impregnated with resins under vacuum before sectioning. Slides were viewed with a polarizing petrographic microscope (Nikon) and images captured with an Olympus ALTRA 20 camera. Total elemental oxide composition of the samples was determined using XRF spectroscopy (X-Lab 2000) and intensity data were collected using the Philips X40 software at the Department of Geological Sciences at the University of Cape Town. Matrix corrections are made on all elements using the de Jongh model in the X40 software. Theoretical alpha coefficients, calculated using the Philips on-line ALPHAS programme, are used in the de Jongh model. Clay mineral analyses was conducted with a Phillips PW 3830/40 Generator with a PW 3710 mpd control X-ray diffraction system using the Xpert data collector/identify software. Reported values are the average of measurements taken in triplicates. New Gasbench II method was used to analyze for stable isotopes ($\delta^{18}O$ and $\delta^{13}C$) composition of carbonate palaeosols at the Archaeometry Research Laboratory, University of Cape Town. Standards used are: Cavendish Marble: crushed marble from Cavendish Square in Claremont. The samples were calibrated in our lab against a commercial reference gas. Mike Hall of Cambridge University also calibrated this marble. Discrepancy between the 2 measurements was 0.35 for the oxygen (−8.95 μs, −8.60) and 0.05 (0.34 μs, 0.39) for carbon. NBS 18, NBS 19, NBS 20 are from the US Department of commerce, bureau of standards samples. Carrara marble and Lincoln Limestone are commercial product, CarraraZ was calibrated at Cambridge by Mike Hall; the new Carrara marble value has been determined against CarraraZ. Reported values are the average of measurements taken in triplicates. Calcium carbonate content of samples was determined by the gravimetric method as described by the U.S. Salinity Laboratory Staff (1954). Scanning electron microscopy was conducted with the Oxford X-Max silicon drift detector and a high resolution Carl Zeiss Σigma Advanced Analytical Microscope. The energy dispersive spectrum was analysed with Oxford INCA software. Reported values are the average of measurements taken in triplicates.

3.3. Interpretive criteria for horizon designation of the palaeosols

Interpretative criteria for horizon designation and taxonomic classification of palaeosols based on combined World Reference Base (WRB-ISRIC-IUSS, 1998), USDA *Soil Taxonomy* (1999) and South African Soil Classification System (SCWG, 1991) approaches are detailed in Tables 1 and 2.

3.4. Palaeosol classification systems

3.4.1. Mark et al. system

This system was widely accepted because it was solely meant for palaeosols although it derives from modern soil classifications of combined USDA *Soil Taxonomy* and IUSS-WRB nomenclatures (Kraus, 1999). It is simple and based on objective principles. A schematic representation of the methods used in designating palaeosols using this method is presented in Fig. 2. It has 18 modifiers: albic, alofanic, argillic, calcic, carbonaceous, concretionary, distric, eutric, ferric, fragic, gleysic, gypsic, nodular, ochric, salic, salicylic, vertic and vitric which could be used to describe palaeosols with more than one dominant property (Imbellone, 2011). For example, a palaeosol with a well-defined gypsic horizon (dominant feature) with an overlying fragic horizon is classified as fragic Gypsisol.

3.4.2. Krasilinikov and Calderón system

This system, which largely derives from the IUSS-WRB concepts and criteria, applies soils properties including texture, structure, mineralogy etc. to classify buried palaeosols. There are 25 higher level classes proposed in this system: Archaeosols, Infrahistosols, Infraleptosols, Infraanthrosols, Infracryosols, Infravertisols, Infrafluvisols, Infragleysols,

Table 1
Interpretive criteria for horizon designation of the palaeosols.

Category	Symbol	Definition[a]	Identifying properties[b]
Master horizons	A	Surface horizon. Accumulation of humified organic matter mixed with mineral fraction	A surface horizon that is darker in colour with finer ped structure than lower horizons
	E	Surface horizon. Underlies an A horizon and is characterized by less organic matter, less sesquioxides (Fe_2O_3 and Al_2O_3), or less clay than underlying horizons.	Lighter relative colour than bounding horizons as a result of abundant quartz. Kaolinisation of feldspar grains.
	B	Subsoil horizon. Shows discernible enrichment in clay, carbonates, sesquioxides, organic matter or obliterated parent material structure.	Change of colour relative to the parent material. Increase in relative ped size.
	C	Parent material	Preserves most depositional structures
Intergrade master horizons	AB	As above, but with A horizon characteristics dominant	
	EB	As above, but with E horizon characteristics dominant	
Subordinate descriptors	g	Gleying from iron reduction	Lower chroma colour, usually 2 or less
	k	Accumulation of carbonates	Carbonate nodules and elevated CaO + MgO/Al_2O_3 ratios.
	t	Accumulation of clay	Presence of silicate clay forming coatings on ped faces, argillans in thin section, and elevated Al_2O_3/SiO_2 ratios.
	v	Accumulation of plinthite	Presence of iron-rich, humus-poor mixture of clay, quartz and other minerals
	w	Development of colour and structure only	Subsoil change in colour and structure relative to surrounding horizons or parent material and does not have significant illuvial accumulations

[a] Adapted from the WRB (2006).
[b] Adapted from Soil Survey Staff (2014) and Retallack (1997).

Table 2
Interpretive criteria for taxonomic classification of the palaeosols.

Nomenclature	Definition	Diagnostic criteria
Argillic[a]	Diagnostic horizon. A subsoil horizon that has at least 1.2 times as much clay as does some horizons above it, or 3% more clay content if the eluvial layer has >15% clay, or 8% more clay if the eluvial layer has >40% clay	Bt horizons that qualify
Calcic[a]	Diagnostic horizon. A subsoil horizon that is at least 15 cm thick, has secondary accumulation of carbonates (nodules) and contains >5% carbonate nodules	Bk horizons that qualify
Cambic[a]	Diagnostic horizon. A subsoil horizon of very fine sand or finer with some weak indication of constituent accumulation that is not enough to qualify as other subsoil diagnostic horizons.	Bw horizons that qualify
Duplex[b]	Marked textural contrast through clay enrichment	Bt horizons that qualify
Plinthic[b]	Absolute iron enrichment; localised hydrogeomorphic segregation with mottling and cementation	Btv horizons that qualify
Ochric[b]	Surface horizon lacking fine stratification and which is light coloured, or thin or has low organic carbon content (usually <0.4%) and free iron oxide contents	A horizons that qualify

[a] From Soil Survey Staff (2010).
[b] From South Africa Working Group (1991).

Infraandosols, Infrapodzols, Infraplinthosols, Infraferralsols, Infrasolonetz, Infraplanosols, Infragypsisols, Infradurisols, Infracalcisols, Infraglossisols, Infraluvisols, Infranitisols, Infralixisols, Infraarenosols, Infracambisols, Negrosols and Ochrisols. The prefix “Infra” is used for modified diagnostic horizons and reference groups of buried palaeosols (Imbellone, 2011). At the sub-levels of abstraction, the prefixes “pedo” and “dia” are used to denote properties generated by post-burial alteration as a result of pedogenesis and diagenesis respectively. However, no prefix is used as a modifier if the origin of the properties is not known.

4. Results

The studied palaeosols varied remarkably in properties spanning macro- and micromorphology, physico-chemical properties, mineralogy, stable isotope composition and geochemistry (see Eze and Meadows, 2014a, 2014b, 2014c, 2015). This study focuses on classification of the palaeosols based on the reported characteristics. The classification of the palaeosols is presented in Table 3. The respective nomenclatures were obtained from systematic description of the palaeosols using their morphological, physical and chemical properties Eze and Meadows (2014a, 2014b, 2014c, 2015). The youngest palaeosol section at the upper section of LBW has a diagnostic calcic horizon (Table 2) with outstanding traces of iron oxide as depicted from the reddish brown colouration. The calcic nature of the palaeosol was established from its strong reaction to dilute hydrochloric acid (HCl). The older palaeosol at LBW at the bottom of the section (Fig. 3) showed abundant mottling or gleying – a strong evidence of redoximorphism. The palaeosols also reacted weakly to dilute HCl and this demonstrates the presence of calcium carbonate. The CaCO3 content is obviously sufficient to give a “calcic” qualifier to the palaeosol as required in the Mark et al. (1993) system. It also has weak horizonation which connotes non-advanced pedogenesis – a property typical of Luvisols (Eze and Meadows, 2014b, 2015) Therefore, the two palaeosols at Langebaanweg Fossil Park (Fig. 3a) qualified as ferric Calsisol (upper section) and calcic Gleysol (lower section) after Mark et al. system; and Infracalcisol and Infraluvisol using Krasilinikov and Calderón system respectively (Table 3).

At Koeberg, the palaeosol had abundant calcium carbonate nodules; reacted strongly to dilute HCl; has light to bleached colour, coarse

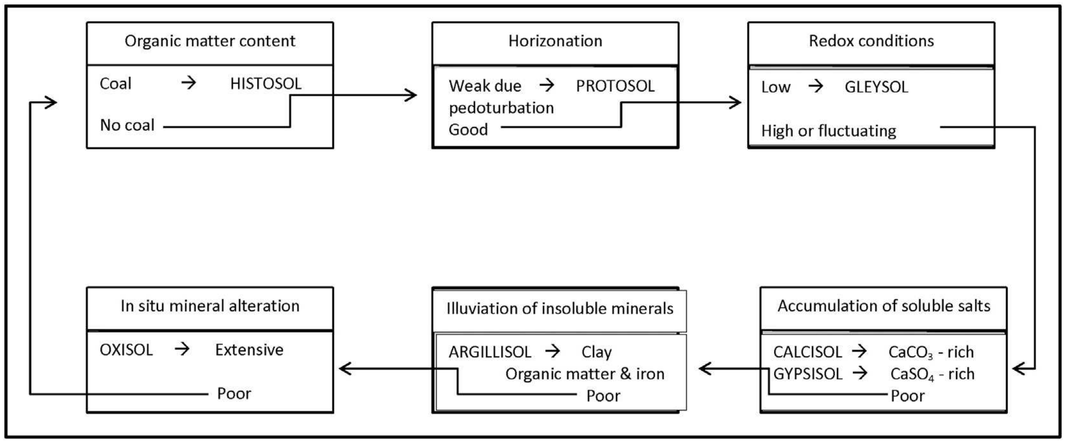

Fig. 2. Simplified order of palaeosol classification based on prominent pedogenic processes in the soil. After Mack et al. (1993).

textured (Eze and Meadows, 2014b). They are Quaternary palaeosols with very thin deposits of Late Holocene sediments (Fig. 3d). It sure was an ochric epipedon going by the properties before the recent sediments began accumulation. The palaeosol therefore keyed out as an ochric Calcisol (Mark et al., system) and Infracisol after Krasilinikov and Calderón system (Table 3).

The palaeosol at Glenhof road at the base of the Table Mountain has a deep reddish colour; fine texture indicative of the heavy presence of plinthite – the soft form of iron-rich, organic poor earthy materials, rich in sesquioxides and has not undergone irreversible hardening and does not slake in water (Eze and Meadows, 2014a). It has an overlying layer of concretions deposited by pedimentation (erosion) of the palaeo surface (Fig. 3b). The largely smooth round nature of the gravels points a grinding effect during transportation by water. It is based on the aforementioned properties that the palaeosols were classified as concretionary Argillisol (Mark et al., system) and Infraplinthisol (Krasilinikov and Calderón system). Similar to the palaeosol at Koeberg, the Quaternary palaeosol at Goukamma Nature Reserve also has an ochric property. It has no remarkable horizonation with fine to very fine sand texture, a true property of cambic horizons (Table 2) (Eze and Meadows, 2014c). The palaeosol therefore qualified as ochric Protosol (after Mark et al., system) and Infracambisol after Krasilinikov and Calderón system (Table 3).

5. Discussion

Divergent opinions abound on palaeosol classification. This is because of the complex and dynamic nature of palaeosols as they occur in nature. Even though there is no universally accepted system at the moment, there is a need to come up with one with the ultimate goal of classifying palaeosols in a way that would take into cognisance the environmental conditions in which they formed and not creating a disparity in communication and understanding between soil scientists and palaeopedologists.

This study has confirmed that the palaeosol classification system proposed by Mack et al. (1993) is quite easy to use, objective and applicable to palaeosols from South Africa. The modifiers are particularly useful in further classifying the palaeosols as they all had more than one dominant property. That notwithstanding, we would propose that this system be further reviewed and updated in the light of our ever increasing knowledge of pedogenesis. For example, the buried palaeosol at Glenhof near the base of Table Mountain has an outstanding presence of plinthite. Considering the fact that plinthite occur in a variety of soils and landscapes on Earth, it would be worthwhile to make a provision for palaeosols well enriched in plinthite in Mack et al. classification system under "illuviation of insoluble minerals" as shown in Fig. 2. The clarity and easy-to-identify nature of the diagnostic properties of the palaeosols in South Africa makes the system of Mack et al. quite easy to use.

On the other hand, at the first level of abstraction, the system of Krasilinikov and Calderón recognises the presence of plinthite in palaeosols and made a provision for it. This is a welcome development as there are possibilities of having significant amount of plinthite-rich palaeosols in South Africa. Although a bit more comprehensive because it is a modification of the ISRIC-IUSS WRB system for modern soils, this method seems quite rigorous in nature. In addition, the system wouldn't be ideal for lithified palaeosols as most of the pedogenic properties of the palaeosol have been altered by diagenesis and difficult to crystal out. This exactly was the case with the Quaternary palaeosols from Langebaanweg (Table 3); they were lithified and their classification using Krasilinikov and Calderón system became very onerous. It proves also very difficult to differentiate between properties of the palaeosols that were acquired from pedogenesis and those from post-burial diagenetic alteration. In this classification, no modifiers were used and the classification of palaeosols did not get to the second level of abstraction in an attempt to avoid potential misinterpretation. In general, caution should be taken and good professional knowledge of soils sought while using this system.

Neither the South Africa Soil Classification system (SWCG, 1991) nor the later grouping into 14 soil groups by Fey (2010) made any references to palaeosols. In view of the fact that all the classification systems proposed for palaeosols evolved from ideas, concepts and definitions of the properties of modern soils, one might be tempted to suggest that these techniques be deplored to palaeosols in South Africa. It may

Table 3
Classification of the selected palaeosols from South Africa.

Location	Age	Type	Structure	Texture	Pedogenic Processes	Horizon	A	B
LBW1	Miocene	Buried	Subangular blocky	Clay loam	Calcification	Calcic (Bk)	Ferric Calcisol	Infracalcisol
LBW2	Quaternary	Buried	Massive	Sandy clay loam	Gleytization	Argilic (Bt)	Calcic Gleysol	Infraluvisol
Glenhof	Cambrian	Buried	Massive	Clay	Plinthization	Plinthic (Bv)	Concrecionary Argillisol	Infraplinthisol
Koeberg	Quaternary	Buried	Subangular blocky	Loamy sand	Calcification	Calcic (Bk)	Ochric Calcisol	Infracalcisol
Goukamma	Quaternary	Buried	Granular	Loam	Leaching	Cambic (Bw)	Ochric Protosol	Infracambisol

LBW: Langebaanweg Fossil Park; A: Mack et al., (1993); B: Krasilnikov and Calderon (2006).

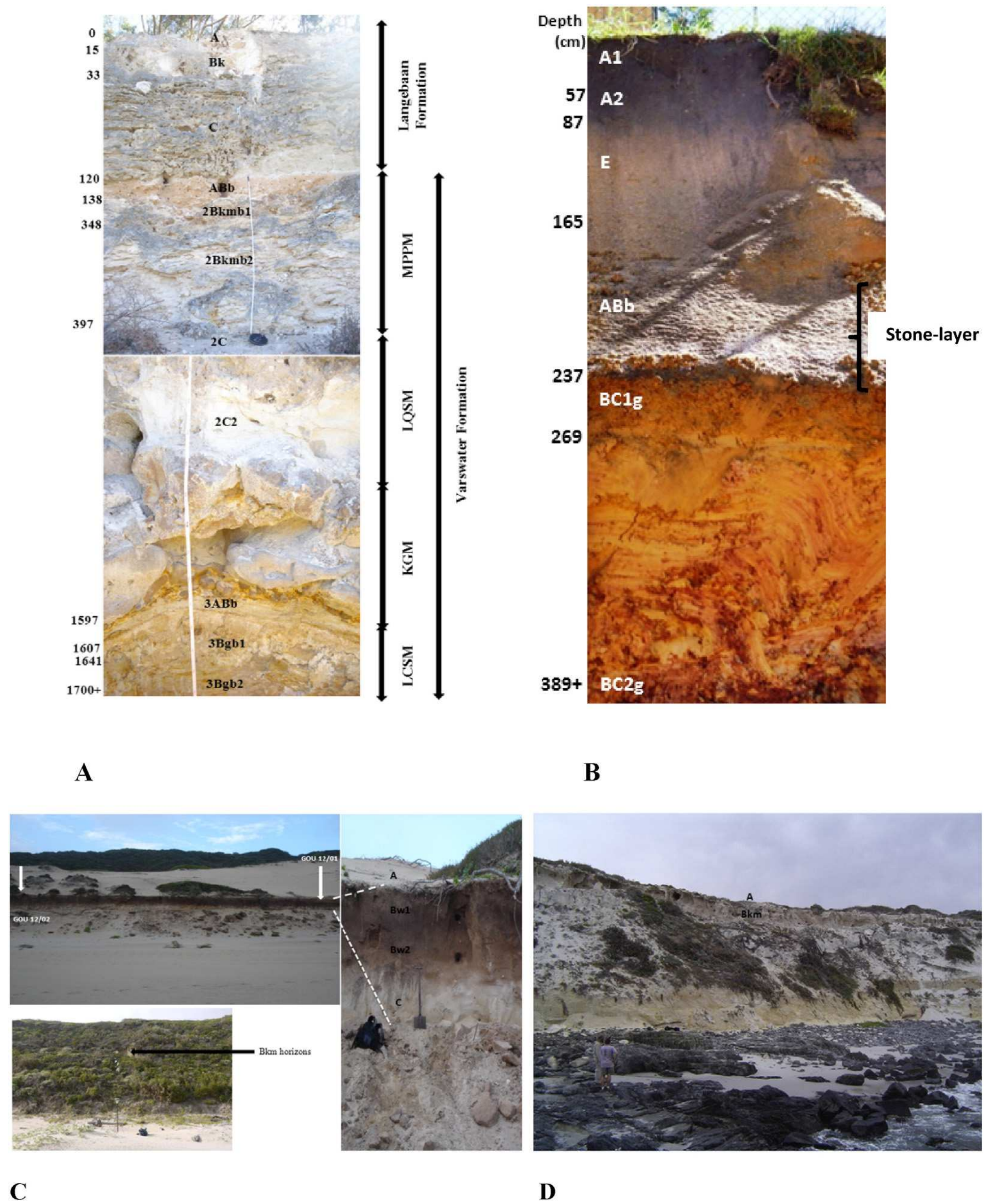

Fig. 3. Cross section of the palaeosols; A: LBW1 (upper section) and LBW2 (lower section); B: Glenhof Road; C: Goukamma; and D: Koeberg.

however not be internationally applauded as such classification scheme would haves limited application within the confines of South Africa alone. More qualitative and quantitative studies of palaeosols of diverse ages and types are needed in South Africa to provide better scientific platform for classification of palaeosols by comparing them with modern soil analogues and existing classification systems for more robust palaeoenvironmental reconstructions and interpretations.

6. Conclusion

Palaeosols in various forms are found in many soils and landscapes of South Africa. They are products of a complex interplay of contemporary climate variables (temperature, precipitation and air circulation), parent material, geomorphology, time and later possibly post-burial alterations. Consequently, it is practically inadequate to classify palaeosols based on the eligibility criteria used for modern soil analogues because great caution is needed to distinguish between primary and secondary soil features of palaeosols formed after burial.

Although there is no universally accepted system of palaeosol classification, the general success of any adopted method would solely lie on the purpose of such exercise. The two systems of Mack et al. (1993) and Krasilinikov and Calderón (2006) evaluated in this study suggests that both are applicable, but strongly need to be further reviewed and modified to achieve the very essence of classification. Mack et al. system would be better for use in South Africa considering its objective and easy-to-use nature which makes for less tedious palaeosol identification in the field. We are however suggesting that another term be coined to take care of palaeosols with preponderance of plinthite. This is the first work that looks into palaeosol classification in South Africa, so further work is recommended to compare and test the suitability of different modern soil classification systems and existing and/or modified existing palaeosol classification systems to palaeosol sections. This would invariably be a big leap in the global quest to achieving a unified and robust palaeosol classification system that will meet all expectations.

Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version, at doi: http://dx.doi.org/10.1016/j.geodrs.2016.06.004. These data include the Google map of the most important areas described in this article.

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