مقالات لاتين

Loess Chronology in Iran

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Upper Pleistocene loess-palaeosol sequences provide excellent high-resolution terrestrial archives of climate forcing in Europe (Frechen et al. 1997, 2003), Central Asia (Frechen & Dodonov 1998; Stevens et al. 2006; Machalett et al. 2008) and in the Caspian Lowland and the Basin of Persepolis in Iran (Frechen et al. 2009; Kehl et al. 2005). The last glacial loess record of Iran has become of interest because chronological methods, such as luminescence dating, make the direct dating of deposition ages of aeolian sediments possible. The quasi-continuous loess record from Northern Iran span numerous glacial-interglacial cycles and make the investigation of long-term synchronicity of climate records in the Northern Hemisphere possible. Multi-disciplinary approaches combining stratigraphy, pedology, sedimentology, palynology, malacology, geochemistry and geochronology can provide a detailed reconstruction of wind dynamics, palaeoclimate and dust flux through the interglacial/glacial cycles of the Middle and Upper Pleistocene in Iran.

The Caspian Lowland of Northern Iran is part of the Eurasian loess belt extending from Northwest Europe to Central Asia and China. During the Pleistocene glaciations, Northern Iran was an extensive area of increased dust accumulation and loess formation. These sediments are widespread covering slopes and interfluves of the piedmont region of Alborz Mountains. Loess comprises a high sensitivity archive of regional climate and environmental changes in the terrestrial record and shows a close relationship with cooling and warming trends for the Quaternary period. The well-developed loess/palaeosol sequences reflect changes in mass accumulation rates of silt-rich sediments and is thus a measure to determine the palaeo-dust content of the atmosphere for the geological past - an important parameter for climate modeling. Furthermore, the loess record of Northern Iran provides a missing link for the correlation between Central Asian and European loess archives. The most complete loess/palaeosol sequences of the Caspian Lowland covering at least the time span of the Middle and Late Pleistocene are located in the area between the Rivers Gorgan and Atrek in Golestan province (Agh Band section) and on the northern foothills of the Alborz Mountains between the cities of Sari and Minodasht (Neka section and Now Deh section).

Little information has been published on records of past climate change in Northern Iran. During the 1960s and the 1970s, loess and the intercalated palaeosols were correlated with moist and dry periods of the Holocene. Later in the 1980s it was suggested that brown palaeosols and loess correlate with the last interglacial period and the last glacial period, respectively. In the Caspian Lowland of Northern Iran, several well-developed palaeosol horizons intercalated in the loess record indicate an alternation of comparatively dry and cool climate phases with increased dust accumulation including loess formation, and moist and warm phases with soil formation, respectively. However, the origin, nature and absolute age of the loess and palaeosol members are still inadequately known and under discussion. Infrared optically stimulated luminescence (IRSL) was applied to set up a more reliable chronological frame for the last interglacial/glacial loess record of the Caspian Lowland in Northern Iran. The aim of this study is to reconstruct regional climate and landscape evolution in Northern Iran for the last interglacial/glacial period, the past 130,000 years. Furthermore, it is aimed to provide data for making a comparison of climate evolution between the Caspian Lowland and the Carpathian loess region in the west and the Central Asian loess region in the east. The increased precision and accuracy of luminescence dating will play an increasingly important role in understanding records of past spatial and temporal variations in dust flux and its relation to global climate change.

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Nature, age and paleoclimatic implications of loess-soil sequences in Northern Iran

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In Northern Iran, loess deposits up to 80 m thick are found along a pronounced climatic gradient from the semi-deserts of the Turkmen steppe (annual precipitation r < 250 mm) towards the subhumid foothill zone of the Alborz mountains (r = ~700 mm) and the Sefid-Rud valley (~1000 mm). The loess deposits in different regions have been studied in key sections using a sedimentological-palaeopedological approach including granulometric, micromorphological, geochemical, and mineralogical investigations as well as numerical age estimates based on the luminescence method (Kehl et al. 2006, Frechen et al., 2009, Khormali et al., in preparation, Kehl et al., in preparation). The main objectives were to elucidate the nature, age and paleoclimatic implications of the northern Iranian loesses.

The grain size distribution as well as the mineralogical and geochemical composition of northern Iranian loesses closely resemble those of typical European or Central Asian loesses. Loess in the Turkmen steppe is comparatively coarse-grained and contains elevated gypsum percentages, up to 12 % high. The loess deposits in northern Iran are divided by several kinds of paleosols and pedocomplexes consisting of weakly developed steppe soils, represented by CBk, Ah or Bwk horizons to strongly developed forest soils (Bht, Bt horizons). The paleosols reflect comparatively humid climatic conditions and stable vegetation covers during the corresponding soil forming periods and their intercalation with unweathered loesses show fluctuations in moisture dependent weathering intensities. The differential degree of pedogenesis during the last interglacial reflects a similar climosequence of soils like the modern soils (Khormali et al, in preparation).

Our preliminary chronostratigraphic estimates of loesses and (paleo)soils will be discussed for two pedostratigraphies proposed for the Sefid-Rud valley and the foothills of the Alborz Mountains. For the last 60.000 years (60 ka), the age estimates are confirmed by physical dating. Based on these data and on correlation of climatic phases with the pollen profiles of Lake Zeribar and Lake Urmia (Van Zeist and Bottema 1977, Djamali et al. 2008) the paleosols can be correlated with interstadial and interglacial periods of the Middle to Upper Quaternary, respectively (Kehl 2009, in press).

The Northern Iranian loesses are excellent archives of Quaternary climate change and landscape evolution. High-resolving studies of granulometry, geochemistry, rock magnetics, stable isotopes and luminescence age estimates may identify more fluctuations in edaphic moisture of the past.

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Facilitating soil salinity surveys with near surface sensing tools

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Land degradation due to increased soil salinity in the lower reaches of the Amu Darya river has become widespread. Leaching of the soils at the end or beginning of the vegetation season is a necessary practice. However, water amount for leaching needs to be determined based on soil salinity level. Salinity is a dynamic property of the soil. Traditional salinity maps based on salinity survey become outdated by the time they are produced, due to time and labour consuming analyses, and may deem obsolete. Electromagnetic (EM) induction is used as a proxy for soil salinity; it measures average electric conductivity of the soil profile down to 1 meter depth. EM technique has shown great potential in fast and frequent sampling which allows producing high-resolution and more accurate salinity maps.
Electric conductivity of the soil depends on many factors such as soil salinity and texture, moisture, and temperature. Studies conducted with an EM device to measure soil salinity at farm scale in Khorezm region demonstrated that this device could accurately detect spatial extent of salinity during cropping seasons in 2002 and 2008. Calibration of EM device to transfer reading into commonly used indicators electrical conductivity of the saturation extract (ECe) or total dissolved solids (TDS) has been conducted. Accurate detection of soil salinity despite various circumstances contributing to variation in soil properties, i.e. irrigation, cropping, and cultivation, showed that EM can be used instead of soil sample analyses. Hence, EM device could be used for soil surveys of the larger areas at the end of vegetation season to determine water requirements for leaching soil salinity.
A salinity survey using EM device in autumn 2003 has been completed within 1 month, in an area covering about 400 km^2. The use of the modified version of the EM device and integration of GPS receiver in 2008 allowed further speeding up and increasing the frequency of sampling locations, since the device makes continuous reading while switched on and carried by operator. The modified version of the EM device allows taking readings from shallow (down to 0.75 m) and deeper layers (down to 1.5 m). An area covering 50 ha could be mapped within 2 days and soil salinity of 0.75 and 1.5 meter layers could be drawn next day.
Such advances are very useful to monitor soil salinity dynamics which represents the basis for evaluation of land reclamation and land management strategies in the Aral Sea Basin.

Saline soils and salinity assessment in western Golestan Province

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Introduction

Soil salinization adversely affects soil fertility and can lead to severe land degradation. Accumulations of soluble salts in the soil increase the osmotic potential of the soil which aggravates the water uptake for plants, an imbalanced ionic adsorption is a second effect. (VAN HOORN & VAN ALPHEN, 1994). Since soil salinization causes yield depression, it is a massive problem for farmers in the lower alluvial plains of Gorgan and Atrak rivers located in the north-western part of Golestan Province.

This area is characterised by a steep climatic gradient: hot, dry climate in the north with mean annual temperatures of about 19°C and 250mm annual rainfall whereas at the northern slopes of the Alborz Mountains in the south, there are slightly lower annual temperatures of about 17°C with higher rainfall of more than 600mm. The depth to water table oscillates from 300 to less then 80 cm below surface due to spatial and temporal variability. The slope of the land surface ranges between 0-1° (MINISTRY OF AGRUCULTURE, 1969), so it is rising very gently from -26m below sea level at the Caspian Sea to -6m below sea level at the town of Incheboron located in about forty kilometres distance to the coastline. The plains are covered by fine-grained calcareous alluvium (EHLERS, 1980).

The aim of this investigation was to characterize salt affected soil profiles of the area and to assess the degree of soil salinization as a basis for further investigations and modelling of soil salinity.

Materials and Methods

The sampling area is located in the west of Golestan Province with the settlements of Incheboron and Agh Ghala designating the easternmost points. Soil profiles of Pahlavidej soil series, Ariadasht soil series saline phase, Aghtappeh soil series solonchak, Kavous soil series and Khazar soil series (MINISTRY OF AGRICULTURE, NO DATE) , located along a N-S and E-W transect, were investigated. The distance of the soil profiles to the Caspian Sea varies from approximately four to forty kilometres. Profiles 1 and 4 are located in non-cultivated areas whereas profile 2, 3 & 5 were under rain-fed farming. Only the field of profile 3 was equipped with an underground drainage system.

Nine additional auger samples were taken from in between the profiles in order to receive a higher spatial resolution. Sampling from the profiles was according to soil horizons detected, whereas the auger samples were taken at defined depths of 0-30, 30-60 and 60-90cm.

The soil samples were dried and sieved on a standard mesh sieve set. The soil texture was determined by a combined sieving and pipette method after destroying organic matter by H_2O_2, dissolving carbonates by $HCl_{(aq)}$ and adding 0,1M $Na_4P_2O_7$ as a dispersion agent. The percentage of carbonates was identified by the volumetric method (SCHEIBLER). Electric conductivity (EC) and pH of the soil saturation extract were measured according to standard laboratory methods (SCHLICHTING ET AL. 1995). The ionic composition of the saturation extract was measured by atomic absorption spectrometry (Na, K, Mg and Ca) and ion exchange chromatography (Cl, SO_4^{3-}, NO_3^- and PO_4^{3-}). Concentration of HCO_3^- was estimated from the ion balance. ESP was estimated according to VAN REEUWIJK (2002).

Results and discussion

The profiles are classified as a sodic Haplogypsid, sodic Haplocalcids and one sodic Haplocambid. The texture is silt loam or loam. The soils were found to be mostly saline sodic or sodic with EC_{SSE} (25°C-normalized) reaching values up to 21,5 mS/cm in the northernmost profile. The soluble salts are mainly dominated by sodium with the sodium adsorption ratio (SAR) ranging from 7,79 to 137,92 mmol/kg and the exchangeable sodium percentage (ESP) estimated from 9,17 to 66,91%. Soil $pH_{(H2O)}$ ranges from 7,76 to 8,87. Table 1 gives an overview on

Parameters	Min	Max	Mean	S.D.	C.V. [%]
Sand [%]	0,0	30,1	4,9	6,2	125,2
Silt [%]	62,7	96,5	84,0	6,5	7,8
Clay [%]	2,0	29,9	11,1	6,5	58,5
pH	7,8	8,9	8,4	0,3	3,2
EC [mS/cm]	0,7	21,5	7,1	5,2	72,5
K+ [$mmol_{eq}$/kg]	0	26	3	4,1	154,3
Ca2+ [$mmol_{eq}$/kg]	6	79	29	16,3	56,6
Mg2+ [$mmol_{eq}$/kg]	13	513	124	104,9	84,9
Na+ [$mmol_{eq}$/kg]	24	1879	547	447,4	81,8
Cl^- [$mmol_{eq}$/kg]	27	2361	606	589,4	97,2
NO_3^- [$mmol_{eq}$/kg]	0	15	4	4,1	96,3
PO_4^{3-} [$mmol_{eq}$/kg]	0	0	0	0,0	177,5
SO_4^{2-} [$mmol_{eq}$/kg]	13	264	99	46,5	47,1
HCO_3^- [$mmol_{eq}$/kg]	0	102	26	26,0	101,8
Total soluble salts [%]	0,05	2,22	0,66	0,4	65,7
Gypsum [%]	0,02	10,04	3,96	3,1	78,8
Carbonates [%]	10,74	35,38	16,98	5,5	32,3
SAR [mmol/kg]	7,7	137,9	59,2	30,0	50,7
ESP [%]	9,2	66,9	43,3	13,3	30,7

Table 1: The mean values, Standard Deviation (S.D.) and Coefficient of Variation (C.V.) of soil physical and chemical properties of the soils investigated

the measured and estimated values of physical and chemical properties of the soils investigated. Sodium concentrations tend to decrease with depth below surface whereas carbonate concentrations slightly increase in most profiles. This indicates an upward directed soil water flux. Salinity and sodicity increase towards the northern part of the sampling area and towards the Caspian Sea. A spatial pattern of salinity seems to become apparent.

Outlook

Further investigations with higher spatial sample resolution will be done to understand the operating processes of soil salinization in that area and to verify the spatial pattern of soil salinization which is assumed. In a second step, the numerical computermodel SAHYSMOD will be applied to the data collected and adjusted to the local conditions to simulate and predict soil salinization.

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Current conditions and improvement of pastures soils of South-Western Tajikistan

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According to large-scale soil mapping data in south -western region of Tajikistan, where the irrigated land is limited, more than 1 million in hectares used as the natural pastures and haymaking areas for livestock development,

Pastures are located at heights from 350-500 to 1600-1800 m above sea level in Vahshsky natural-economic area and from 600 900 to 3000-3500 m in Kizilsu-Yakhsu area. A steepness of pasture areas varies from $2\text{-}5^0$ to $30\text{-}45^0$ with prevalence of slopes of 5-15-30 degrees which are considered optimum, especially in Vahshsky region.

Climatic conditions of region depending on vertical belts is characterized from very dry-extra arid with daily summer temperature $28\text{-}30^o$ and annual precipitation 208 mm to moderately-dry with in daily temperature $18\text{-}20^o$ and annual rainfall from 569 - 741 mm in low mountain areas to 1011мм in high-mountainous belt.

The vegetative cover of pastures of characterized regions are various, as botanical structure, and biological efficiency. On river terraces and plains vegetation it is presented meadow with productivity 4-5 c/ha, desert formation with productivity 1,5- 5 t/ha. Results of numerous experiments with different types and dozes of fertilizer applications on various types of mountainous pastures of Tajikistan shows the high efficiency of fertilization. Application 45-60 kg of nitrogen and 30 kg per 1 ha phosphorus (P_2O_5) –in spring at the start of vegetation increases pasture productivity 2-3 times. On average out of 53 experiments performed on grass stands of grass-of-short-grass and tall grass of semi savanna and meadow pastures and hayfields on piedmont area with a norm of $N_{60}P_{30}$ kg/ha the growth of yield per 1 kg NP active material of fertilizers made 26.3 kg of dry matter.

Unsystematic grazing, over loadings, de forestation, wrong receptions of economic activities and other anthropogenesis negative influences led to degradation of pastures, deterioration of botanical structure and to sharp decrease in efficiency of grasses. The results of last large-scale soil mapping showed, that a considerable part of soils of pastures here (60 %) are subject by erosion. This problem can be solved or mitigated with the better organization of pasture rotation and wide application of a complex of anti erosion and a pasture - ameliorative measures.

Proceeding from it, we developed some scheme for sustainable use of pastures.

I. Water harvesting measures

1. To keep snow by creation of snow platens and creation of wood strips;
2. Rationing the number of livestock for grazing;
3. Pasture rotation;
4. Stop grazing in degraded pastures;

II. Superficial improvement of pastures.

1. Reseeding of degraded pastures.
2. Protect pastures from weed and poisonous plants
3. Stone harvesting;
4. Application of mineral fertilizers;

THE CURRENT SITUATION OF SOIL resourses IN TAJIKISTAN AND THEIR PROSPECTS IN FUTURE

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The total area of Tajikistan is 14 million ha, 93 % of them mountains. Agricultural lands account for 23% of the total area, the relief is extremely varying from 300 m above sea level to 7495 m. Tajikistan as mountain country is characterized by vertical belts.

The climate is sharply continental with low air humidity, considerable fluctuation of annual and daily temperatures, minor quantity of precipitation and also long, hot, arid summer and short winter. Average winter temperatures vary between -3°C and -20°C, but can fall below -45°C in the mountain regions. Average summer temperatures vary between 19°C and 32°C. Average annual precipitation is 338 mm, varying from less than 70 mm in the plains and deserts to 2 400 mm in the mountains.

Distinctive feature of soils in many vertical belts, as a whole in Tajikistan is the low content of organic matter and nutrients, very high erodibility, unfavorable drain status of soils that are limited by a poor maintenance of drainage system.

The path to democracy and market economy for Tajikistan has had many setback as well as political and socio-economic shocks. Developing a democracy from a turbulent past is a difficult and slow process. However, some positive progress has been made and many changes are visible. We established so-called private sector, new types land use system, free price system for agricultural products and there is a relatively good economic activity. Compared to 1995, total agricultural production has trend for increase. The international community has encouraged the efforts to move towards democracy and free market reforms by supporting several development projects.

At the same time during last decades Tajikistan faced with the numerous problems in agriculture:

- decreasing the yield of crops, especially cotton two times.
- increasing the area of eroded land.
- increasing the area of saline and waterlogged soils.
- content of organic matter and available nutrients in soil decreased.
- application of mineral and organic fertilizers decreased 10 times.
- desertification

The main reasons of existing situation are:

- new farmers are short of investment for reclamation of soil.
- state land ownership and mismanagement.
- uncontrolled cultivation of sloped land, converting slope pasture land to rainfed

Land and soil recourses. Historically in ancient time Tajikistan has been one of the main agricultural centers. Cotton has been produced for almost a century; thus, the soil productivity currently has become very low. During the Soviet time, agriculture was characterized by high rate of mechanization use; heavy use of chemical fertilizers and pesticides; development of monoculture in the regions and by use of excessive quantities of water for irrigation. As a result, soil deterioration has become dramatic. Although substantial resources were allotted for agricultural intensification during 70-90th, the farm yields in the last decade of transition have decreased. According to this data, around 2% of the total area in the Tajikistan is cropland, 25% is rangelands, 4 % is forest, 64,8% other areas. Irrigated area is 75% (of the cropland)

Soil Degradation. However before to estimate degradation processes which seized territory of the republic, it is necessary to mention that Tajikistan is one of the most mountainous countries. The standard estimation is: 93 % of its territory is mountains and only 7 % of it is leveled valleys. Vakhsh natural-economic area is situated in the less mountainous part of Tajikistan. Thus there are no high mountains. Nevertheless more than 55 % of its territories are considered to be mountain lands. More mountainous is the territory of Sugd natural-economic area - almost 73%. The most mountainous are Kulab and Hissar natural-economic areas – 84% and almost 91% accordingly. First of them contains territories concerning lowland plains (Kizilsu-Jahsu valley). The territories of Kharm and Badahshani Kuhi Autonomy Region are whole inside mountain systems. The levelled sites of their territories are small in mountain hollows in the bottoms of mountain rivers gorges and on cone of sediments of their tributaries. Exception is East Pamir plateau with its extensive river valleys of Murgab, Alichur and bottoms of Karakul, Rangkul and other lakes. However the plateau is raised on the height more than 3500 m above sea level and that is why the whole territory is in the high mountains. Mountain ranges, foothills and intermountain valleys are in continuous physico-geographical interconnection. Its factors are water drain, gravitational field and atmosphere circulation. Each of them is specific in economic as well as in agricultural relation. Thus analysis of orographic data shows that almost 90% of republic territories are covered with mountain ranges and foothills. Rest 10% is so-called lowland valley of such large rivers as Amu-Darya, Sir-Darya, Panj, Vakhsh, Zeravshan and their tributaries. However, in economic relation the picture looks different. All irrigating agriculture is concentrated in rivers' valleys, and no irrigated agriculture, gardening and part of forestation (pistachio bushes) are in the foothills. 90% of agricultural production is produced in irrigated zones and more than 9/10 of country population lives there. The complex analysis of climatic and soil parameters shows wide distribution of desertification-degradation phenomena in Tajikistan. According to soil data and existing classifications the most part of its territories should be referred to various types and subtypes of deserts and semi-deserts. Each of them is characterized by an originality of natural condition complexes and by high-altitude belts location. General review of Tajikistan territory shows that the country is situated between two different leveled desert belts – lowland and high-mountain, very hot and cold. The specification of features of these deserted belts together with humidification allows considering that there are two types of desertification process: arid hot subtropical and arid cold high-mountainous (frozen). In landscapes with ground humidification and poor draining of both types of deserting salt accumulation in soils, and underground waters develops. If the management of this irrigated land is inappropriate, salt accumulated on the ground surface, making it impossible to continue cultivation on such land. There are 4 types of deserts and 1 type of semi-deserts on Tajikistan territory which are subdivided on 10 subtypes. Undoubtedly, during more detail researches the number of them can increase according to hierarchical attribute. They are different size on the occupied area from several thousand hectares and less, up to several millions hectares, totally making 54 % from the area of RT. In geographical aspect they are either fragments of vertical soil-climatic belt or the whole belt itself. However one of desert types - gravitational, by its expanding fragments is extended from below (lowland plains) up to snowy and glacial tops, where super high-mountain district forms. Genetic feature of deserts and semi-deserts is that all of them are of natural origin, which are appeared and developed as a result of Pamir-Alai and Tian-Shan mountain systems formation.

SOIL AND DESERTIFICATION PROCESS ON THE PAMIRS MOUNTAIN ECOSYSTEMS

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The Pamir mountain ecosystem is a most part of the territory of Tajikistan. Taking into account characteristic feature of the Pamir region we can divide this region into three parts: Northern, Western and East. We shall note only, that Northern part consists of ridges: Zaalaysky, Peter 1 and the Academy of Sciences.

Absence of the uniform developed principle of soil classification and diagnostics in Tajikistan, including the Pamir, makes inconvenient detailed elaborations and their application in various branches of sciences, an agriculture and cartographical works. Up to present among soil sanctities there are various, frequently inconsistent interpretation in the names and soil classifications the Pamir region.

On the basis of review our field expeditions during 1979-1987 years and 2000-2008 years, literary and archival materials submit the following soil classification on the Pamir: mountain light brown soil type; high-mountainous meadow -steppe type; high-mountainous steppe type; high-mountainous deserted - steppe type; high-mountainous deserted type; high-mountainous zangoviy type; high-mountainous takir type; high-mountainous meadow type; high-mountainous meadow -marsh type; high-mountainous marsh type; high-mountainous solonchak soils type.

Besides on the Western Pamir from the settlement Andarob up to the settlement Lyangar in limits the type of soil juniper forests is allocated a subtype relic soil juniper forests, and on Panj and Pamir river banks - soil type, which was became the steppe. Around of large lakes the sandy soil type is allocated. All above mentioned soil types are subdivided into subtypes. Some soil types depending on prescription of development are subdivided into irrigated and not irrigated subtypes.

Studying of Pamir soil has allowed characterizing existing natural interrelations between separate soil groups and factors of soil formation. On the basis of this approach of Pamir soil classification and diagnostics was developed for the scientifically-grounded mapping of soil resources with a view of their rational use, protection and reproduction.

Almost all Pamir soil is subject to a different degree of erosion and a deflation. On East Pamir wind erosion prevails of water erosion. There is barchans in height up to 4 meters around of large lakes are located. Slopes of mountain ridges on East Pamir are cut numerous erosion denudations by forms of a relief (obburida – cut by water). On Northern and Western Pamir only water erosion develops. And mountain slopes these regions are very strongly cut by obburids and gullies. Density of these forms on some sites reaches 7,6 km/km^2. In considered region denudation process prevails of processes of the raising mountain ecosystem.

There are not big sandy massive of an alluvial origin on the banks of large rivers in the Western Pamir, which are submitted as not so big barhkans, the speed of movement of which reaches some tens meters per one year.

For Pamir we except obburide allocate special type of water (snow) erosion – small stream, i.e. after thawing snow very fine negative relief forms are formed.

Except for erosive processes on the Pamir other kinds of desertification are allocated also, such as salinization and ground water which have local distribution and have the insignificant areas.

It is necessary to note, that in places of the most intensive influence of a wind the small sites of deflation plains with attributes of clear removal by wind are found out which are usually on a direction of a wind pass in sand - deflation loops, covering soles of slopes, which are especially represented in northern east of isolated terrain features Kosh - Agyl, in area of lakes Karakul and Rangkul and in Alichur valley. In some places of examined territory there are sandy dunes. Sand-deflation loops with bright expression of wind erosion are characteristic for a valley of the river Pianj in Ishkashim district.

In the bottom part of alpine areas the pasturable erosion is developed, in nival zone denudation processes are advanced. Wash-out of soils in a alpine zone depending on projective covering of vegetation and exposition of slopes makes from 1,5 up to 120,4 t/ha. The slopes of a southern exposition are strongly subject to water erosion, than northern and the surface erosion here is less by 10 - 100 times, than in southern. Ravine erosion in alpine zone is advanced poorly.

The special place in orography of Alpine spaces the high uplands of East Pamirs with glacier, nival and deflation processing occupy. Ranges of East Pamirs differ from the ranges of erosion-denudation Alpine areas by a smaller steepness and dividedness of slopes, capacity of water flows, engendering on slopes these of ranges, is insignificant, therefore they do not form deep gorges, as it is observed on Western Pamirs.

On the basis of space photos soil and erosion maps are made.

Expanding Clays in Rhizosphere Soils and its Implications to Nutrient Cycling

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Abstract

Rhizosphere soils are the most active sites in the transformation of minerals in soil system. The presence of bacterial communities and mycorrhizal associations constantly modifies the soil solution composition leading to a dynamic nature of minerals in the root-soil interphase. The demand for K and Mg by organisms and host plants renders instability to K and Mg-containing silicates due to constant changes in pH and nutrient contents (e.g., K and Mg) in rhizosphere soils. Decreases in K or Mg concentrations in solution enhance the breakdown of micaceous or chloritic minerals into expanding 2:1 clays characterized by basal spacings ranging from 1.41 to 1.52 to 1.79 nm upon Ca-saturation and glycerol solvation depending on mycorrhizal species, nature of micaceous minerals, host plant species and growing season. Rhizosphere soils of *A. lasiocarpa* dominated by *Piloderma*, an ectomycorrhizal fungi, had significantly higher vermiculite+smectite to chlorite ratio (2.2) than other rhizosphere (1.9) and non-rhizosphere soils (1.6). These variations in ratios and spacing reflect differences in charge density and are measures of the ability of clay to store cations such as K and Mg. In addition, the breakdown of phyllosilicates to expanding clays is a reversible process. These expandable 2:1 clays play a role in biogeochemical cycling of K, Mg (and other cations) because of their ability to fix or release K, Mg (and other cations) as demanded by organisms and its associated host plants.

Introduction

Rhizosphere soils (RS) provide nano- and microsites for the most intense interactions between organisms, mineral, gaseous and solution phases in soil systems. In forest ecosystems, plant roots are colonized by several ectomycorrhizal (EM) fungi where each symbiosis is a very specific RS system. There are a minimum of 347 and 280 different root-fungus symbioses (= RS = EM) associated with *Fagus sylvatica* and *Nothofagus dombeyi*, respectively (Kottke 2002). In agricultural soils, Blackwood and Paul (2003) and Miethling et al. (2003) described many unique bacterial community structures associated with various RS. These nano- and microenvironments are active sites for mineral precipitation, elemental speciation, nutrient cycling, soil structural formation and environmental remediation (e.g., Banfield and Navrotsky 2001, Benzerara et al. 2008, Hochella 2002). The rate of breakdown for mica and chlorite to 2:1 expandable clays and other hydroxyl-interlayed minerals (HIM) was predominant in RS compared to non-RS (e.g., April and Keller 1990, Courchesne and Gobran 1997, Glowa et al. 2004, Hinsinger et al. 2001, 2006).

Recently, Huang et al. (2005) summarized the implications of mineral–organic matter–microorganism interactions on the development of innovative management strategies to sustain ecosystem health on the global scale. They indicated that microbial activity can accelerate the breakdown of minerals by as much as six orders of magnitude. The interaction of organisms and minerals impacts agriculture, waste management, and the water industry, as well as the natural and semi-natural environment in the Earth's critical zone (Young and Crawford 2004, Brantley et al. 2006).

The objective of this presentation is to review the state-of-knowledge of biologically-mediated formation of clays in rhizosphere soils to elucidate nutrient cycling. Specifically, we will determine the role of expanding clays as storage and/or reservoir for exchangeable cations, particularly potassium and magnesium, in forested and cropped areas.

Ectomycorrhizal fungi, clay mineral and chemical compositions

Smectites, vermiculites and hydroxyl-interlayered minerals (HIM) are the most common expanding clays found in rhizosphere soils. Hinsinger et al. (2006) reported that vermiculite formation from phlogophite was observed after 14 days when grown with rye grass (*Lolium multiflorum*); they further argued that similar high-charged clays can form from the transformation of mica within 2 days in the RS. However, these high-charge clays either are not stable and decreases in amounts (e.g., Courchesne and Gobran 1997) or may form in the RS zone (e.g., Hinsinger and Jaillard 1993; Kodama et al. 1994).

The amount and types of expanding clays are strongly influenced by the type of ectomycorrhizal fungus association in RS (e.g., Arocena et al., 1999; Glowa et al., 2004). The clay minerals produced by EM associated with roots of *Picea glauca* (white spruce) produce a significant amount of expandable clay (1.79 nm in Ca saturation and glycerol solvation) which largely collapses upon potassium saturation. Ca – saturation in the air dried state shows 1.41 nm spacing, instead of the normal hydrated (two water layer) state of 1.52 nm. The soil materials not associated with the EM (or non-rhizosphere) did not show significant expandable clay material but strong chlorite peak (Fig. 1)

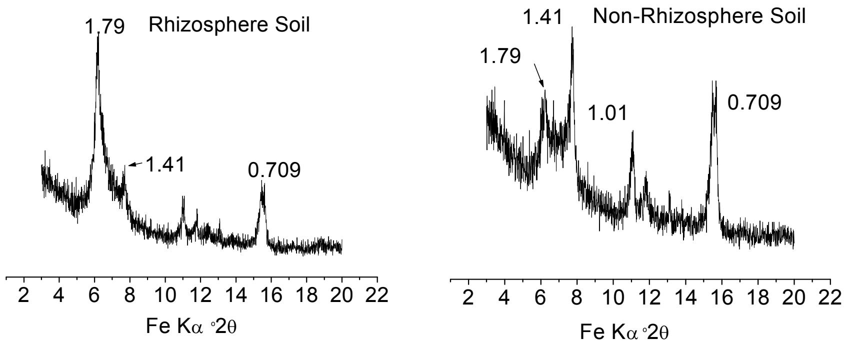

Fig. 1. X-Ray diffractograms of Ca-saturated and Glycerol-solvated clay fractions of rhizosphere and non-rhizosphere samples of hybrid spruce (*Picea glauca*) showing the relative intensities of the 1.7- and 1.4-nm reflections indicative of vermiculite (Vt) + smectite (Sm) and chlorite (Ch), respectively. The 1.0-nm peak suggests muscovite (Mus) (modified from Glowa et al. 2004)

The influence of fungal species on the nature of expandable clays in rhizosphere soils are summarized in Table 1. RS-A in the two studies are dominated by *Piloderma* and both had higher amounts of Vt+Sm compared to N-RS samples. In *A. lasiocarpa*, RS-A had significantly higher amounts of (Vt+Sm)/Ch than RS-B and N-RS. (Vt+Sm)/Mi ratios in RS-A and RS-B were not significantly different from each other. However, the ratios of (Vt+Sm) over mica or chlorite in RS-A and RS-B for both tree species were higher than N-RS samples.

Exchangeable cations in RS and N-RS samples varied according to the colonization by ectomycorrhizal fungi; the influence of fungi differed depending on the host tree species as well. In *P. glauca*, exchangeable K in RS-A and RS-B were similar and were significantly higher than N-RS while for *A. lasiocarpa*, K content in RS-A was significantly higher than in RS-B but both had higher exchangeable K than N-RS samples. Calcium and magnesium contents in RS soils were in *P. glauca* were not significantly different from each other; exchangeable Ca and Mg in RS-A were higher in RS-A than RS-B in *A. lasiocarpa*. In addition, Ca and Mg in the latter were similar to those in N-RS soils.

Reports on soil pH and other chemical properties between RS and N-RS soils sowed no consistent trends (Tables 1 and 2). Arocena et al. (1999) and Glowa et al. (2004) measured higher pH in RS than N-RS soil in contrast to similar soil pH in RS and N-RS soils determined by Turplault et al. (2007). Courchesne and Gobran (1997) reported that oxalate-extractable Fe and Al were significantly higher in rhizosphere than bulk soils (Table 2). Turpault et al. (2008) reported 8 mg Al kg^{-1} soil citrate-extractable Al in rhizosphere soil compared to 6 mg Al kg^{-1} soil citrate-extractable Al in bulk soil.

Table 1. Mean and (standard deviation) of the contents (g kg^{-1}) of expandable phyllosilicates in clay fraction, and pH, exchangeable K, Mg and Ca (cmolc kg^{-1} soil) in RS-A, RS-B and N-RS soils in two tree species (data from Arocena et al. 1999; Glowa et al. 2004)

	Picea glauca (*n=6*)			*Abies lasiocarpa* (*n=3*)		
	RS-A	RS-B	N-RS	RS-A	RS-B	N-RS
Vt + Sm	105 (10)	94 (7)	95 (22)	185*a* (24)	200*a* (24)	160*b* (14)
(Vt+Sm)/Mi	0.56 (0.04)	0.55 (0.08)	0.48 (0.09)	1.1*b* (0.13)	0.97*b* (0.14)	0.73*a* (0.06)
(Vt+Sm)/Ch	1.13 (0.37)	1.07 (0.42)	1.03 (0.47)	2.2*b* (0.28)	1.9*a* (0.23)	1.6*a* (0.04)
pH	4.1*a* (0.13)	4.3*a* (0.15)	5.1*b* (0.17)	4.6 (0.25)	4.9 (0.26)	5.2 (0.60)
Exch. K	0.29*a* (0.06)	0.32*a* (0.04)	0.17*b* (0.04)	0.32*a* (0.01)	0.25*b* (0.02)	0.15*c* (0.01)
Exch. Mg	0.84 (0.24)	1.11 (0.27)	0.78 (0.34)	1.1*a* (0.05)	0.74*b*	0.64*b* (0.05)
Exch. Ca	2.65*ab* (0.67)	3.34*a* (0.76)	2.36*b* (0.69)	8.1*a* (0.37)	5.6*b* (1.1)	4.2*b* (0.37)

Within each tree species, means followed by the same letter across each row are not significantly different ($P > 0.05$); in *A. lasiocarpa*, RS-A = *Piloderma* (66 %); RS-B = *Mycelium radicis atrovirens* and cottony yellow-brown types or where *Piloderma* spp. colonization was <2% (Arocena et al. 1999); in *P. glauca,* RS-A = *Piloderma* (93 %); RS-B = *Inocybe lacera*-like and *Hebeloma*-like morphotypes or where *Piloderma* spp. colonization was <1 % (Glowa et al. 2004)

Seasonal variations in clay and chemical compositions

Variations in clay mineral and chemical composition in RS and N-RS environments are also influenced by the growing season (Turpault et al. 2008). They reported that the magnitude of 2:1 minerals that collapsed upon K-saturation was smaller for samples collected in rhizosphere than bulk soils. Also, the XRD reflection at 0.994 nm was higher in intensity in rhizosphere than those in the bulk sample.

The temporal changes in mineral composition are complemented by changes in cation exchange capacity (CEC) and chemical composition (Table 2). CEC and the ratio of exchangeable K/CEC measured in June were higher compared to observations in March for both bulk and rhizosphere soils. The ratios of exchangeable Mg and Ca to CEC exhibited trends in contrast to K/CEC ratio for RS and N-RS samples. Exchangeable Ca/CEC ratio in bulk soil was significantly higher in June than March, and CEC in determined in June were higher than observations in March for both bulk and rhizosphere soils.

Table 2 Mean (and SD) contents of selected chemical properties of bulk and rhizosphere in surface soils

	Bulk soil	Rhizosphere	Reference
Oxalate-extractable Al (g kg^{-1})	6.5*a* (1.3)	12.5*b* (3.1)	Courschesne and Gobran 1997
Oxalate-extractable Fe (g kg^{-1})	18.9*a* (4.1)	25.2*b* (4.3)	Courschesne and Gobran 1997
Citrate-extractable Al (g kg^{-1})	8	6	Turpault et al. 2008
pH	3.93 (0.13)	3.94 (0.09)	Turpault et al. 2007
March			
CEC (cmol kg^{-1} soil)	17.0*ax* (2.1)	16.9*ax* (2.2)	Turpault et al. 2007
Exchangeable K/CEC	3.0*ax* (0.4)	5.6*bx* (1.6)	Turpault et al. 2007
Exchangeable Ca/CEC	16.5*ax* (3.6)	15.0*bx* (5.0)	Turpault et al. 2007
Exchangeable Mg/CEC	4.5*ax* (1.5)	3.6 *bx* (1.2)	Turpault et al. 2007
June			
CEC (cmol kg^{-1} soil)	18.3*Ay* (2.2)	18.8*Ay* (2.5)	Turpault et al. 2007
Exchangeable K/CEC	3.7*Ax* (2.4	7.0*Bx* (3.0)	Turpault et al. 2007
Exchangeable Ca/CEC	14.6*Ay* (2.7)	14.2*Bx* (3.8)	Turpault et al. 2007
Exchangeable Mg/CEC	4.1 *Ax* (0.9)	2.9 *Bx* (1.0)	Turpault et al. 2007

For Turpault et al. (2007), *a* and *b* are used to compare bulk and rhizosphere soils sampled in March; *A* and *B* compared soils sampled in June; *x* and *y* are used to temporal effect between March and June; means followed by different letters are significantly different at 95%

Discussion and implications to nutrient cycling

Biologically-mediated mineral transformation

Soil mineral transformations occur largely in soil microenvironments and processes vary considerably in space and time due to significant influence by microorganisms. Organisms in rhizosphere soils are responsible for the changes in the soil solution composition resulting from soil processes at the soil solid/soil solution interface (e.g., Arocena and Glowa 2000, Arocena et al. 2004, Hinsinger et al. 2006). For example, low pH in RS samples is believed to be a contributor to the breakdown of soil minerals and the increased availability of K^+ (and $Ca^{2+}$and Mg^{2+}) in soil solution (Arocena and Glowa 2000). Most of the changes in soil solution are associated with the increased uptake of water and nutrients by the host plants that are facilitated by mycorrhizal associations. Active plant uptake of nutrients such as K and P is known to lower their concentrations in rhizosphere soils, hence drive the soil processes towards the release of K (and P) and the breakdown of K (and P)-containing minerals (e.g., Hinsinger et al. 2001, Jungk 2002, Arocena et al. 2004, Hinsinger et al. 2005).

The uptake of K is of a special interest because it is required by plants in high quantities almost at levels equivalent to N (Hinsinger et al. 2001) implying a fast and high rate of removal from K-containing minerals. The most common source of K into the rhizosphere soil solution results from the release of non-exchangeable K from the interlayer K contained in K-bearing phyllosilicates such as micas and illites. The removal or release of K from phyllosilicates transforms mica and illites to expandable 2:1 minerals such as vermiculite and smectite (e.g., Arocena et al. 1999, Glowa et al. 2004, Hinsinger et al. 2006). K-released from interlayer free-up the negative charge and allows the K-free 2:1 structure to retain hydrated ions, hence its expansion to larger basal spacings (e.g., 1.5 to 1.8 nm) depending on the ambient conditions.

Fungal species are also known to influence the rate of K release, hence the transformation of micaceous minerals. Arocena et al. (1999) and Glowa et al. (2004) reported that the presence of *Piloderma spp*. *Inocybe lacera*-like and *Hebeloma*-like morphotypes in RS accelerate the transformation of mica (and chlorite) to 2:1 types of expandable clays compared to N-RS soils. *Piloderma* colonization increased the phosphorus uptake of Norway spruce seedlings (Arocena et al. 2004) and provides more available K to host plants through accelerated weathering of biotite (Glowa et al. 2003) when compared to soil not colonized by ectomycorrhizal fungi. The differential influence of ectomycorrhizal fungi on the breakdown of mica maybe attributed to the variations in physiological needs of the fungi and/or host plants for potassium.

Implications to biogeochemical cycling

It is well known that expandable 2:1 clay minerals fix and release K ions from and into solution depending on the environmental conditions. Officer et al. (2006) noted the significant relationship between plant available non-exchangeable K and 2:1 clay mineralogy. Hinsinger and Jaillard (1993) reported the release of K from phlogopite (a mica species) when the K^+ concentration in the rhizosphere fell below 80 mmol dm^{-3} and resulted to the formation of expandable 2:1 clays. In addition, Barré et al. (2008) observed that the breakdown of phyllosilicates to expanding clays is reversible. This ability to fix or release K led Barré et al. (2007a, 2007b) to postulate that 2:1 minerals behave as a K reservoir in soils and significantly play a role in biogeochemical cycling of K.

The release and fixation of K^+ in 2:1 clays in rhizosphere soils are influence by ectomycorrhizal fungi. In seedlings colonized by *Piloderma croceum*, K^+ in soil solution close to the roots (<1.0 cm) of Norway spruce was significantly lower than those seedlings not-colonized by ectomycorrhizal fungus (Arocena et al. 2004). In Arocena and Glowa (2000), the concentrations as well as the activities of K^+ in solutions followed the order RS-A > RS-B > N-RS (see Table 2 for the ectomycorrhizal colonizations of the samples).

The nutritional demands of plants and organisms for essential elements such as K influence the biogeochemical cycling. Turpault et al. (2007) reported that processes such as H^+ production by roots and/or the organic matter degradation and uptake of K vary with season (e.g., March vs June),thus the differential formation of expandable clays in the rhizosphere soils. For example, hydroxy-Al polymers precipitated in vermiculite interlayers between March and June. Seasonal changes in mineral composition are further supported by the increase in CEC between March and June for the N-RS, and aluminium precipitation outside the interlayers for the RS samples. They concluded that rhizosphere mineral and chemical compositions as excellent indicators for understanding both the short- and long-term nutrient dynamics in ecosystems.

Knowledge of the elemental dynamics in rhizosphere soil is important to the understanding of nutrient availability to sustain life forms in the Earth's Critical Zone.

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Mineralogy and geochemistry of loess-soil sequences in Northern Iran

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Introduction

In Northern Iran, loess deposits, up to 80 m thick, are found along a pronounced climatic gradient from the semi-deserts of the Turkmen steppe (annual precipitation r < 250 mm) towards the subhumid foothill zone of the Alborz mountains (r = ~600-800 mm). The climatic gradient has a strong influence on the horizon differentiation, clay content, organic matter and clay mineralogical composition of modern loess soils (Khormali et al., in preparation), and different kinds of loess palaeosols (Kehl et al. 2006; Frechen et al., 2009) also suggest differential degrees of soil formation and weathering in the past. These are closely linked to past climatic conditions, if other factors of pedogenesis were constant. In that case, the palaeosols could be defined as climaphytomorphic (e.g., Bronger et al., 1998) and would represent excellent archives of past climate change.

For palaeoclimatic reconstructions based on palaeosol types and weathering degrees, the lithologic homogeneity of the parent materials must be tested. So far, little information has been published on the mineralogical and geochemical compositions of loess deposits in northern Iran (e.g., Ohkravi & Amini, 2002; Karimi et al., 2008). We therefore characterised the mineralogical and geochemical composition of the three loess key sections at Neka, Now Deh and Agh Band (Kehl et al., 2006).

Methods

The palaeosols selected range from weakly developed steppe soils, represented by CBk, Ah or Bwk horizons to strongly developed forest soils (Bht, Bt horizons). Based on pedostratigraphic reasoning and luminescence age estimates (Frechen et al. 2009) and correlation with other geo-archives of past climate change (Kehl 2009), these palaeosols can be correlated with interstadial or interglacial phases. 38 Samples of the different palaeosol horizons and corresponding parental loesses were analysed including the mineralogical composition of the carbonate-free silt and clay fractions by X-ray diffraction. Bulk samples were also analysed for their calcium carbonate equivalent (volumetric method), gypsum percentage (extraction with ethanol), and contents of major and minor elements (X-ray fluorescence) as well as free (Fe_d) and total (Fe_t) iron (ICP-OES).

Results

The grain size distribution (Kehl et al., 2006) and the mineralogical and geochemical composition of northern Iranian loess deposits closely resemble those of typical European or Central Asian loesses. Carbonate contents of unweathered (primary) loess layers range from

8-20 %. Loess of Agh Band section is comparatively coarse-grained and contains elevated gypsum percentages, up to 12 % high.

The mineral assemblage of the lime-free sand+silt fraction is dominated by quartz (33-47 %) and plagioclase (19-27 %), with minor proportions of K-feldspar (6-11 %), illite/muscovite (7-20 %) and chlorite (6-13 %). In addition, hornblende (< 5 %) and rutile and anatase (1 %) were found. The ratio of quartz/plagioclase (Qu/Plag) ranges from 1.2 to 2.5. There is a slight tendency of reduced absolute plagioclase contents in strongly developed Bt horizons, compared to parental loess or other soil horizons. Overall, the relative proportions of minerals and the Qu/Plag ratio do not exhibit consistent differences between loess and/or paleosol layers. The comparatively low variation in quartz percentages by weight suggests a petrologic homogeneity of the soil horizons and parental loesses.

The coarse clay fraction is mainly composed of illite (55-75 %) and primary chlorite or vermiculite (10-45 %), the latter occurring only in samples of the Neka section. Smectite and kaolinite often occur in traces and attain maximum amounts of 10 % and 20 %, respectively. The absolute amounts of illite and chlorite/vermiculite are in general higher in the soil horizons than in the corresponding parental loesses. The fine clay fraction (<0.2 µm) is mainly composed of illites (35-75 %), smectite and/or mixed-layer expandable clay minerals (Sm/ML, 15-40 %) as well as chlorite and/or vermiculite (Chl/V; 10-25 %). Kaolinite occurs in traces. In the fine clay, Sm/ML are relatively enriched probably as a result of both, pedogenetic clay formation and enrichment of fine clay by clay illuviation. Absolute amounts of clay minerals increase considerably in well-developed Bw(t) and Bt horizons compared to the parental loesses. In these soil horizons, Sm/ML values rise in a sequence from Agh Band over Neka to Now Deh. This indicates that under the climatic (semi-arid) conditions of Now Deh, smectite formation and illuviation was favored.

The major elements SiO_2, Al_2O_3 and CaO are found in high concentrations, while the contents of Fe_2O_3, MgO, Na_2O and K_2O are moderate, and those of MnO, TiO_2, P_2O_5 and SO_3 are low on average (Table 42). The large variation of the CaO content (y) is explained mainly by the $CaCO_3$ equivalents (x) of the samples, which result from different primary carbonate contents of loesses and from differential carbonate leaching and secondary carbonate enrichment. The two variables exhibit a strong positive correlation ($y = 0.064x + 1.51$; $r^2 = 0.996$, n = 38) and the SiO_2 contents decrease with increasing CaO contents.

A comparison of the geochemical composition of the parental loesses shows that the highest average SiO_2 contents are found in loess from the section at Agh Band, which also shows slightly higher SiO_2/Al_2O_3, SiO_2/Fe_2O_3 and Na_2O/Al_2O_3 ratios than loesses at Neka and Now Deh. These differences are related to larger proportions of quartz and higher concentrations of soluble salts such as NaCl at Agh Band. In addition, the SO_3 concentrations are significantly higher at Agh Band, owing to high gypsum contents. The K_2O/Al_2O_3 ratio does not show significant differences between the loesses and ranges from 0.16 and 0.20 for all samples, including those taken from soil horizons. Most minor elements are slightly to strongly enriched in palaeosol horizons compared to the parental loesses, except for La and Sr, showing an indifferent reaction or a strong depletion, respectively.

Free iron (Fe_d) is enriched in palaeosols compared to parental loesses. The enrichment was largest at Neka section, and considerably less at Agh Band and Now Deh. In addition, the Bt and Bw(t) horizons gave, except for one soil, consistently higher absolute enrichments than Bwk or CBk horizons.

Overall, the mineralogical composition and geochemical data suggest that the weathering intensity even of the most strongly developed soils is still limited. Differences between the soil horizons are mainly due to different degrees of carbonate leaching and loss in major and minor elements, such as sodium, magnesium and strontium. A near-neutral pH in decalcified horizons of modern soils underlines a still initial stage of mineral weathering, which probably applies also to all palaeo-Bt horizons even before partial recalcification from the overlying loess.

Conclusions

The parental loesses are mineralogically and geochemically more or less homogenous. Differences in the mineralogical composition of palaeosols are small, whereas the geochemical composition shows differential degrees of weak to moderate weathering which indicate different climatic conditions during interglacials and interstadials of the Quaternary in Northern Iran. The differential degree of pedogenesis during the last interglacial suggests a similar soil climosequence like the one at the present land surface.

High-resolution studies of granulometry, rock magnetics, stable isotopes and luminescence age estimates may identify more fluctuations in edaphic moisture of the past. The Northern Iranian loess-soil sequences are excellent archives of Quaternary climate change and landscape evolution in this ecologically diverse area.

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