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The inorganic chemistry of peat from the Okavango delta (fan), Botswana: implications for low-ash coal formation

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ABSTRACT

The Okavango Delta is a large land-locked alluvial fan located in the northwestern part of the semi-arid Kalahari basin of northern Botswana. The geographic position of the Okavango system is controlled by a southwest extension of the East African rift system; sediment is presently accumulating in a graben defined by northeast-bounding faults. Depositional slope and gradient are low, 1:3600, and the fan sediments cover 18,000 km^2. Seasonal floodwaters from the catchment in tropical Angola disperse on the fan creating both perennial (12,000 km^2) and seasonal swamps (6,000 km^2). Distributary channels on the fan surface are confined by vegetation, consisting mainly of *Cyperus papyrus* L., but these channels are unable to accomodate water flow. Therefore, water movement occurs mainly outside of the confined channels and it is this sheet-like dispersement of water which sustains plant growth and peat accumulation and preservation. The dispersal of water also results in severe water loss and over 95% of the water is lost by evapotranspiration.

A complex relationship exists between the inorganic chemistry of macrophytes and that of the peat in the perennial swamps of the Okavango fan. Living and decaying plants and peat from a portion of the swamp were analyzed chemically and mineralogically to determine the process involved in peat production. Chemical changes in the macrophytes commence at the onset of senescence as a result of nutrient recycling and further changes occur due to leaching by rainwater. During subaqueous decay, major changes in inorganic chemistry occur, some components being lost, others gained, while major mass loss occurs. While major changes in inorganic components occur, during decay, peat formation does not fractionate the O/C or H/C ratios.

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However, the C/N ratios declines markedly during decay, probably due to bacterial activity, and reaches low values (approximately 12) in peat.

Ash content of peat declines downstream from a maximum of 70 wt.% to approximately 40 %. Average ash analyses yield 20% quartz, 40% kaolinite and 30% plant-derived silica, mainly from phytoliths. Therefore, 90% of the peat ash is accounted for by allochthonous detrital mineral matter and plant silica, while the remaining 10%, which includes Fe, Mg, Mn, Ca, Na, K and P is difficult to account for. Ion exchange is unimportant in concentrating these elements, and bacterial activity may be an important process for their uptake in peat. The uptake of these elements by the peat is an important mechanism for offsetting salt build-up which should occur due to the severe evapotranspiration losses. Sodium, however, is only weakly taken up by the peat and plants and accordingly sodium salts (trona and thermonatrite) dominate evaporite deposits on the delta's islands.

Peat is a powerful scavenger of those inorganic components which are essential to the living plants. In the normal evolution and dynamics of the swamp system, channels and adjacent peat swamps ultimately become moribund and are abandoned. In the prevailing semi-arid climate, this abandoned peat rapidly desiccates and becomes susceptible to fire. Peat fires burn on several fronts and at varying depths, thereby reducing several meters of peat to a thin residual ash layer. Inorganic nutrients form part of the resultant ash and, through bioturbation by burrowing animals and insects, these enrich the otherwise sterile, sandy soils that characterize the substrate. Subsequent reflooding of a burnt-out area is promoted by topographic inversion of the landsurface caused by the peat fires.

This study has important implications for the origin of low-ash peats and coals in general. In order that a peat swamp might form at all requires an appropriate geomorphological setting in which perennial, laterally extensive, shallow flooding can occur. This setting must survive for a substantial period of time to allow sufficient time for significant peat accumulation. An essential requirement for prolonged peat accumulation is a very low input of bedload and suspended inorganic detritus in the fluvial systems that drain into the swamp. In the proximal reaches of the swamp, ash content may be volumetrically small but large on a mass basis. Ash content declines slowly and irregularly through the system, and is controlled by the distribution of channel systems. The wide dispersal of inorganic detritus appears to be due to a low degree of flocculation, which inhibits filtration. Nevertheless, such filtration of allochthonous detritus in the proximal reaches is an important stage in the production of low-ash peats. In the distal reaches, the proportion of allochthonous detritus is very low and ash contents are accordingly also low. The composition of the ash changes significantly and it appears that metal uptake in such regions may be a function of bacterial activity. When bacterial activity declines to low levels, possibly in the most distal reaches of such a swamp or in the deeper peat, very low-ash peats will result, which must be essential precursors to low-ash coals.

DISCUSSION

M. Teichmüller (F.R. Germany)
Comment: A microscopic study of the strikingly black (probably highly decomposed) peat is recommended. Peats from arid climates (with salt crusts!) are very rare and exceptional.

Response: We have not yet conducted a petrographic study of our peat and will pursue this line of research as soon as possible.

C.L. Chou (Illinois State Geol. Survey)
Question: Why are the detrital minerals composed mainly of kaolinite and quartz? How are they related to the nature of the source area?

Response: The detrital minerals are of aeolian (wind-transported) origin. There are also other minerals present, but they are of minor importance volumetrically. The source of the quartz is from Tertiary aeolian Kalahari sand with little input of primary quartz eroded out in the catchment area.

E.I. Robbins (U.S. Geological Survey)
Question: Do you have any sulfur bacteria, sulfur oxidizers, or sulfur reducers in the salt pans?

Response: We have not identified any such bacteria. A reason for this may be the very low amount of nutrients in the system which does not permit abundant biogenic activity. Sulfur is also very low in the swamp water.

E.I. Robbins (U.S. Geological Survey)
Question: How do you get all those salts like trona precipitating out? Is there a condition of oversaturation?

Response: There is no oversaturation of Na. The trona is precipitated by capillary action on the islands. Intense evaporation takes place due to the semiarid climate and the sodium salts, trona and thermonatrite, form soft crusts on the island sands.

L. Ruppert (U.S. Geological Survey)
Question: If non-detrital mineral matter is being produced by bacteria, why do you have a gradient in proximal and distal production? Is it due to pH-Eh conditions, elemental concentration differences?

Response: The general decrease in non-detrital mineral matter is probably related to a drop in bacterial activity from the proximal to the distal areas.