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Evidence for a geochemical origin of the mysterious circles in the Pro-Namib desert

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ABSTRACT

The origin of the so-called "fairy circles" has not yet been established. Carbon monoxide (as an indicator of a natural gas microseep) was monitored inside and outside of the selected fairy circles in the Namib, Namibia, Southern Africa. Hydrocarbons were extracted from the soil by a novel method for trapping analytes onto silicone rubber designed for thermal desorption into a gas chromatograph–mass spectrometer (GC–MS). Unresolved complex mixtures with resolvable alkanes were detected in soil collected from two newly formed circles. Alkenes, the microbial degradation product of alkanes (microbial food source), were more abundant in the circles compared to the levels of alkenes detected in the matrix between circles. Results show a microseepage of gases and hydrocarbons which is expressed at the surface as a geobotanical anomaly of barren circles and circles of altered vegetation. In addition, this finding may suggest a new approach to the origin of the mima mounds (*heuweltjies*) of the Western Cape in South Africa.

1. Introduction

Traditional Himba folklore holds that beneath the edge of the Namib Desert lies a crack in the earth's crust in which a dragon lives and whenever it exhales bubbles of fire rise to the surface, burning and vaporising the vegetation, forming circles (Carte Blanche, 2004: transcript of televised interview with Dr W. Jankowitz; De Vita, 2006). The origin of the enigmatic pock mark ("fairy circle") patterned landscape of the Namib Desert has fascinated scientists and the general public for many decades. In many arid and semi-arid environments around the world striking vegetation patterns have developed (Borgogno et al., 2009; Rietkerk et al., 2004; Van Rooyen et al., 2004). Self-organised vegetative patterns of spots, labyrinths, gaps and stripes can arise in response to competition for limiting water and nutrients (Rietkerk et al., 2004). Spots are small round-shaped clusters of vegetation interspersed within a bare soil background while gaps are round-shaped bare soil islands surrounded by homogeneous vegetation (Borgogno et al., 2009). Currently there is no scientifically sound explanation as to the cause of fairy circles: circular depressions (Fig. 1a and b) (Jankowitz et al., 2008) which are devoid of vegetation and are often surrounded by a fringe of tall grasses (Van Rooyen et al., 2004). These circles occur in a broken belt in the Pro-Namib zone of the west coast of southern Africa, approximately between 60 and 120 km inland, extending from southern Angola through Namibia to just south of the Gariep (Orange) River in South Africa (Van Rooyen et al., 2004).

The first reference to the fairy circles was in 1971 when Tinley proposed that the circles were the remains of fossil termitaria (Van Rooyen et al., 2004). In 1978 a group of researchers from the University of Pretoria began investigating the origin of the mysterious circles (Theron, 1979). Eicker et al. (1982) reported on a microbiological study of the barren circles in the Giribes Plain, but did not explain their origin. Theories as to the cause of these circles were related to termite activity, to localised radioactivity and to allelopathic compounds released by dead *Euphorbia damarana* plants, none of which provided conclusive evidence (Van Rooyen et al., 2004). According to Becker (2007) the foraging behaviour of harvester ants and harvester termites are the prime causal factor for the development of fairy circles under certain conditions. The fairy circles have been linked to the mima mounds ("heuweltjies") of the Southern and Western Cape in South Africa (Albrecht et al., 2001; Lovegrove, 1993). These mounds are believed to be ancient termite nests. As the calculated dispersion indices for mounds and circles were remarkably

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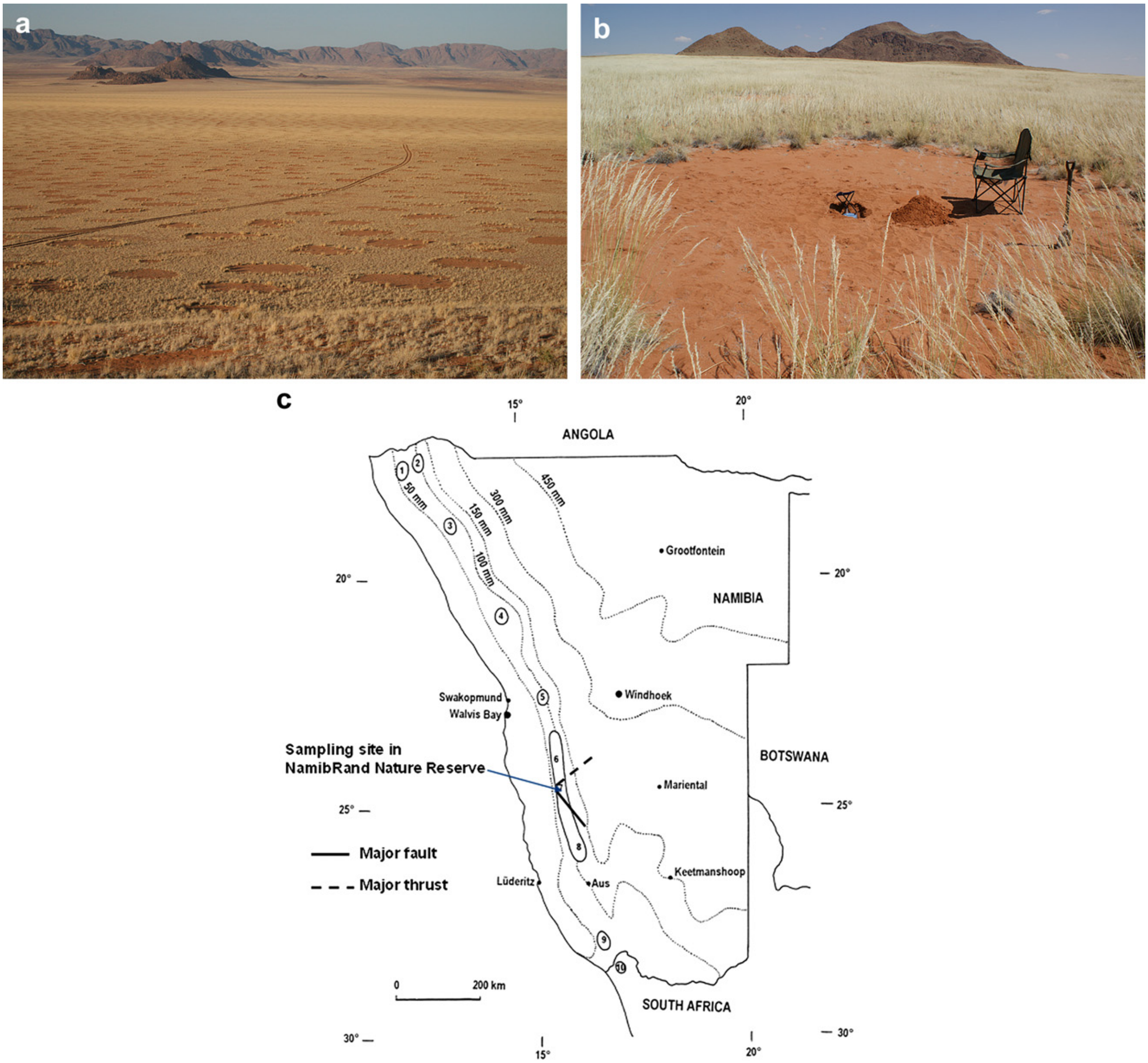

Fig. 1. (a) Pock marked landscape of the Pro-Namib desert. (b) Circular patch of barren soil in the NamibRand Nature Reserve in Namibia, southern Africa. (c) Map of Namibia indicating the approximate location where gases were monitored and soil samples were collected in NamibRand Nature Reserve and of some major faults and fault thrusts in the vicinity of the sampling site.

close, Albrecht et al. (2001) proposed that termites were involved in both phenomena and that the fairy circles were caused by a substance associated with termite nests. In order to explain the circular shape of the patches, Albrecht et al. (2001) proposed that the biologically active factor central to their hypothesis may be a semi-volatile chemical substance. However, if the factor could diffuse readily to form a circular patch in which inhibition of plant growth occurs, there would need to be an active process whereby the agent is constantly replenished (Albrecht et al., 2001). Jankowitz et al. (2008) concluded that the results of their *in situ* investigation could be interpreted as supporting Albrecht et al.'s (2001) argument that a "semi-volatile gas" produced in the circle inhibits grass growth.

Surface macroseeps (visible hydrocarbon seepage such as oil) and microseeps (invisible, usually detectable by sensitive instrumentation or the visible result of their effect on the near-surface environment) occur because diffusion, effusion and buoyancy (micro-gas bubbles) allow hydrocarbons to escape from sources and migrate to the surface (Jones et al., 2000; Mello et al., 1996; Van der Meer et al., 2000; Yang et al., 2000). The surface expression of a geochemical microseep can take many forms including geobotanical anomalies, anomalous hydrocarbon concentrations in soil, water and atmosphere, microbiological anomalies, anomalous non-hydrocarbon gases, mineralogical changes such as the formation of calcite and certain magnetic iron oxides, and altered magnetic properties of soils (Jones et al., 2000; Schumacher and LeSchack, 2002; Yang et al., 2000). Most geochemical signatures display as apical or halo-like (Schumacher and LeSchack, 2002). An apical anomaly, e.g. hydrocarbons, is greatest above the source and a halo anomaly occurs towards the edge of the source, outside of the anomaly, or forms a circular pattern around an apical anomaly. A general model of hydrocarbon-induced geochemical and geophysical alteration of soils illustrates anomalous surface concentrations (apical or halo formation), carbonate precipitation, bacterial degradation of hydrocarbons, high resistivity anomaly at