Causes of Silicification, Tension Joints and Different Degrees and Directions of Dips of Nubian Sandstones Outcrops in Khartoum State

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Abstract

Nubian Sandstone outcrops north of Khartoum State are arenaceous with fossils and horizontal, while in central and south are ferruginous, argillaceous, dipping in different directions, with tension joints and no fossils. Field work targeted all outcrops in the study area; methods include description, measurements, and petrographic analysis. The present work referred silicification and Petrified wood formed as a result of hydrothermal alteration by silica derived from adjacent basement complex.Different directions of dips and tension joints is attributed to intrusion of Late Tertiary basaltic rocks in central area.

Key words: arenaceous sandstone, silicified fossils, Hudichert, tension joints, dips and intrusion.

مستلخص

الحجر الرملي في شمال ولاية الخرطوم يتصف بالتواضع الافقي والرابطة السليكونية وتواجد الاحافير، بينما في الوسط والجنوب تسود روابط اكاسيد الحديد والرابطة الطينية تختلف اتجاهات الميل والفواصل التوترية و تنعدم الاحافير. الدراسة الحقلية استهدفت كل الحجر الرملي في منطقة الدراسة، وشملت طرق الدراسة كل من: الوصف، القياسات، الاختبارات الفيزيائية والميكانيكية بالإضافة للتحليل الضوئي. الدراسة تعزي ظاهرة سيادة اكسيد السليكون والاحافير في شمال المنطقة الى التغير الهايدروحراري بواسطة السليكا المشتقة من معقد صخور الاساس المجاورة. اختلاف اتجاهات الميلان والفواصل التوترية في وسط منطقة الدراسة تعزى الى اقتحام الصخور البازلتية في التكوين النوبي في العصر الثالث المتأخر.

الكلمات المفتاحية: الحجر الرملي ذو الرابطة السسليكونية، الاحافير الخشبية السليكونية، تكوين الهودي، الفواصل التوترية، الميل والاقحام.

Introduction

The study area is bounded by 15° 15′ 00″- 16° 20′ 00″N, and 32° 15′ 00″- 32° 45′ 00″ E (Fig.1). The formation was known as Cretaceous Sandstones in 1837 in upper Egypt, changed to Nubian sandstones [1], then the term Cretaceous Sandstone applied to sandstone bodies in most countries of the north Africa and in Arabian peninsula, and for the rocks ranging from Cambrian–Cretaceous. The term Nubian Series was used by [2] and [3]. The terminology of the sedimentary cover rocks of the northern Sudan has been subjected to discussion and reclassification by different authors [4]. Hudichert is considered as facies of Upper Nubian Sandstone Formation [5]. Khartoum region Nubian Sandstones Series is considered to be Late Cretaceous in age [6]. In order to avoid confusion Barazi [7] used the term Nubian Sandstone Formation Khartoum type for the sandstone around Khartoum instead of Nubian Sandstone Formation for the sedimentary succession around Khartoum State. Hussein, [8] proposed tropical fluviatile environment, but Omer [9] suggested semi-dry to tropical paleoclimate. The flow was a SE–NW direction as shown by paleocurrents direction measurements [10,11,12]. The nature of the sedimentation is fluviatile.

Nubian Sandstones around Khartoum is almost fine to medium, coarse and very coarse sandstone is about 5% of the formation. Pebbly sandstone is 10% [8]. The Nubian Formation generally is characterized by cross-bedding sand sedimentation; this texture is more prevalent in Upper Omdurman Formation. Cross stratification results from old channels divagation in flat subsidizing zones [13]. From economic point of view, the Nubian Formation has a good reserve of kaolinite deposits which is being exploited in ceramic and bricks manufacturing, in addition to bentonite deposits. The Formation bears no base minerals except low grade of iron oxides at some horizons-Fe_2O_3-up to 53% which is very limit in horizontal and vertical extensions such as at Bijrawiya area. Nubian Sandstone Formation is the most important water bearing geological formation in Sudan both in quantity and quality [9]. The objective of the study is to interpret prevalence of siliceous sandstone, silicified wood fossils in the northern, absence in southern and central part of the study area, presence of tension joints and dipping in deferent directions in at central outcrops.

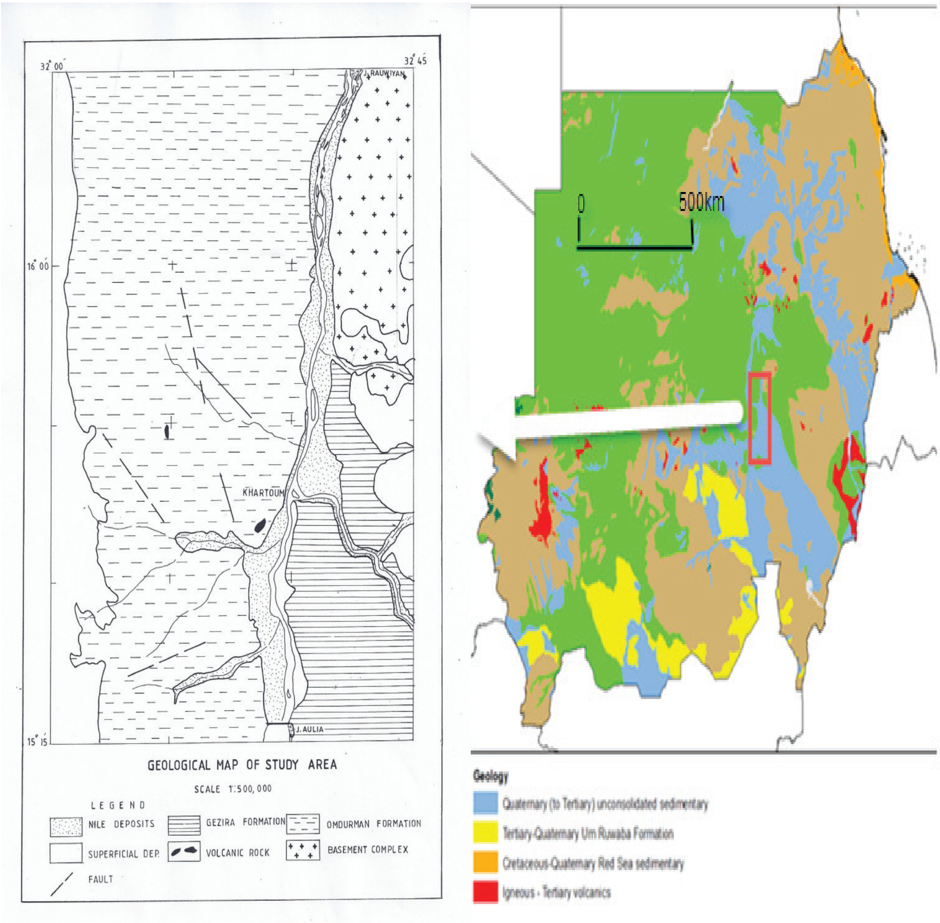


Fig (1). Geological and location map of Sudan and study area.

Materials and methods

The study covered almost the whole outcrops of the Nubian Sandstones in Khartoum State: J. Auliya, J. Atteena, J. Rawyan, J. Om Marrahi (Shaikh Attayeb), Karari mountains, Al-Markhiyat mountains, and all surrounding hills (Fig 2). All outcrops have been described in term of successions, grain-size ranges, shape of grains, lithofacies, thickness of strata, height of the outcrop, checking strength of rocks by geological hammer, Schmidt Hammer, tension joint,joints directions, joints spacing, cementing materials, dips and strikes (Table 1). Fresh representative samples were collected for laboratory tests.

Physical and mechanical tests carried out are: compressive strength, abrasion values, crushing values, specific gravity, impact values, water absorption, density, point load and soundness, as well as petrographic study. All the tests were carried out in accordance with (IS).

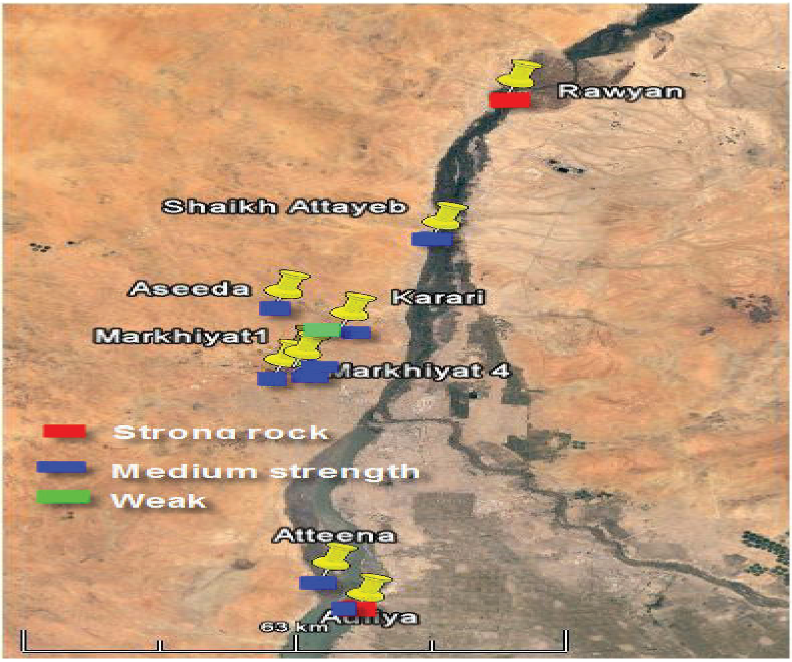


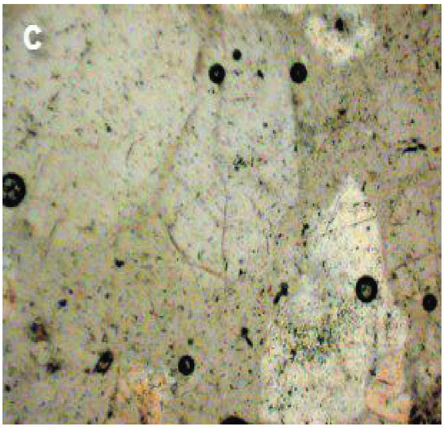
Fig .2. Distribution of Nubian Sandstones in the study area.

Table 1. Geological characteristics of different localities of sandstone outcrops.

Locality	Coordinates	Main layers	Grain size	Thickness (m)	Cementing materials	Height (m)	Sets of tension joints	spaces and directions of tension joints	Rebound readings	Dip
J. Auliya	15 14 16.4 N 32 29 34.3 E	3	Fine, fine, fine.	17, 07, 13	Iron oxide and mud, Clay, Iron carbonate	38	1	6 NW	31 and 42	1 5 º S.
'J. Rawyan	16 15 09.7N 32 36 58.5 E	3	Fine, Medium to coarse, Fine medium	21, 47	Silicon oxide, Silicon oxide and mud.	93	-		41	-
J. Karari	15 47 33.9.N 32 27 24.5 E	2	Medium to coarse	42, 07	Silicon oxide	49	-	-	26.4	3 0 º N
J. Aseeda	15 50 2.5 N 32 22 55.7 E	2	Medium, Coarse,	54, 7	Clay. Silicon oxide with iron oxide	61	1	9EW.	18	3 0 ºN
J. Hardan	15 43 31.3 N 32 24 20.8 E	2	Medium, conglomerate	45, 3	Clay, Silicon oxide with iron oxide.	48	1	1 0 EW.	24.9	1 0 º NW
J. Markhiyat 1	15 42 50.4 N 32 24 32.3 E	2	Medium, Fine.	34, 3	Clay, Silicon oxide	57	-	-	36.1	2 0 º NE
J. Markhiyat 2	15 42 50.3 N 32 24 32.3 E	2	Medium	12, 3	Clay, Clay with iron oxide	15	-	-	30.6	25º E
J. Markhiyat 3	15 42 37.3 N 32 22 11.2 E	2	Fine, conglomerate.	15, 5	Iron oxide, Iron oxide with silicon oxide.	24	1	11 EW.	20.4	30º NW
J. Markhiyat 4	15 41 51.0 N 32 23 19.1 E	4	Medium, Very coarse, Medium to fine.	13, 3, 5, 10	Clay, Iron carbonate	31	-	-	35.9	10º NW
J. Markhiyat 5	15 44 55.4 N 32 24 19.4 E	2	Coarse	15, 3	Clay, Iron oxide with silicon oxide	18	-	-	28.9	5 º W
J . ShaikhAttayeb	15 58 39.3 N 32 32 55.1 E	2	Pebbly medium, Conglomerate.	28, 6	Silicon oxide	34	1	20 NS	34.9	
J. Atteena	15 17 52.8 32 27 27.7 E	2	Conglomerate, Fine	4, 11	Iron oxide	15	1	7 NS	28.2	1 5 º NE

Results

It is noticed that sandstone outcrops north of the study area are almost arenaceous, while that in center and south area are argillaceous and/or ferruginous (Plate 1, and 2), with some silicified wood fossils which increase north and northwest directions, where big silicified trees were noticed in Wed Alhabashi and Hush Alkafir in the River Nile State [14]. On the other hand whereas the northern outcrops show almost horizontal strata, the Nubian sandstone outcrops in central area dip in different directions and degrees (Fig. 4) and show tension joints ranging from 6 up to 240 per 10 m in different directions (Table 1). Frequency of occurrence of tension joints in a bed of rock depends upon: physical properties of the rock bed, physical properties of the surrounding rock beds, thickness of therock bed, and degree of the tectonic deformation [15]. These tension joints and different directions of dips in center of the study area indicate uplift. Cementation process is controlled by sedimentary basin, solubility of quartz increases with increasing temperature and pH value in access dissociation of silicic acid [16]. Comparison between Nubian Sandstone outcrops in central and northern study area is showed by Table (2).



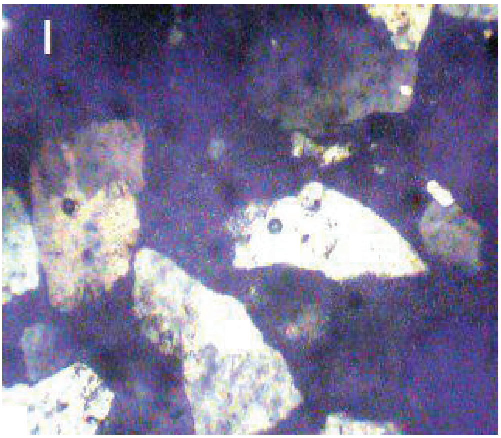


Plate 1. Thin sections c, and l are from J. Rawyan and ShaikhAttayeb (northern outcrops), they are silicon oxide cemented (under parallel nicols, ×4).

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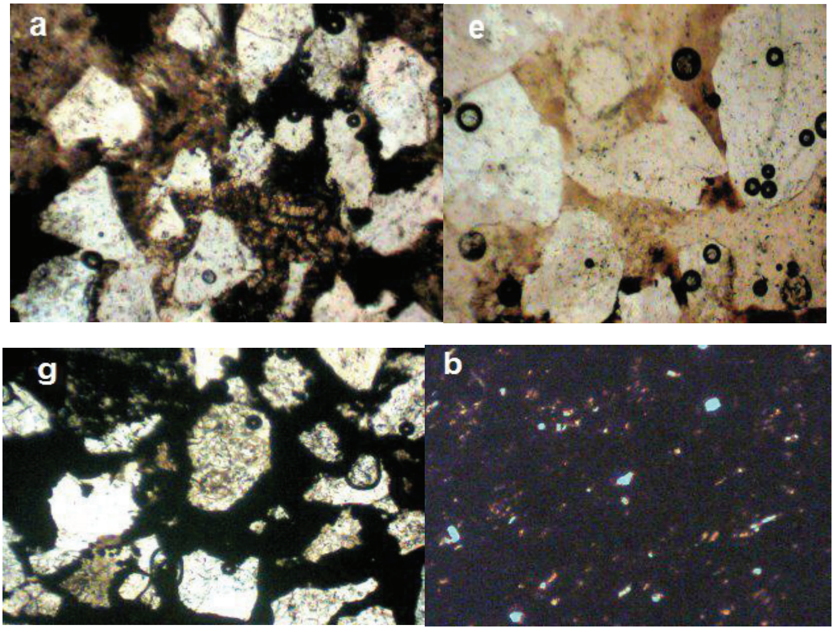

Plate 2. Thin section a, b, are from (J. Auliya), e and g are from (J. Karari and J. Hardan), cementing materials are iron oxides and/or clay. Thin sections b and g are pure ferruginous, e is pure argillaceous, and a is cemented by both clay and iron oxides (central and southern area), a, e and g under parallel nicols ×4, b is under crossed nicols × 10.

Table 2. Comparison between Nubian sandstones at northern and southern study area

Characteristic	Northern outcrops	Southern outcrops
Dip degree range Direction	No dip	5^o-30^o All directions
Range of tension joints space and direction	No tension joints.	6-240 all directions
Fossils	Silicified wood fossils.	No fossils, or might be very rare.
Sandstone types	Siliceous	Argillaceous and ferruginous
Cementing materials	Silicon oxide.	Iron oxides and clay.
Range of rebound hammer readings	32.7-41.0	11.6-38.4
Petrographic analysis	Quartz, mica, feldspar and accessory minerals cemented by silicon oxide.	The same content cemented by iron oxides and clays.
Range of uniaxial compressive strength	48.7-81.8 Mpa	23.8-93 Mpa

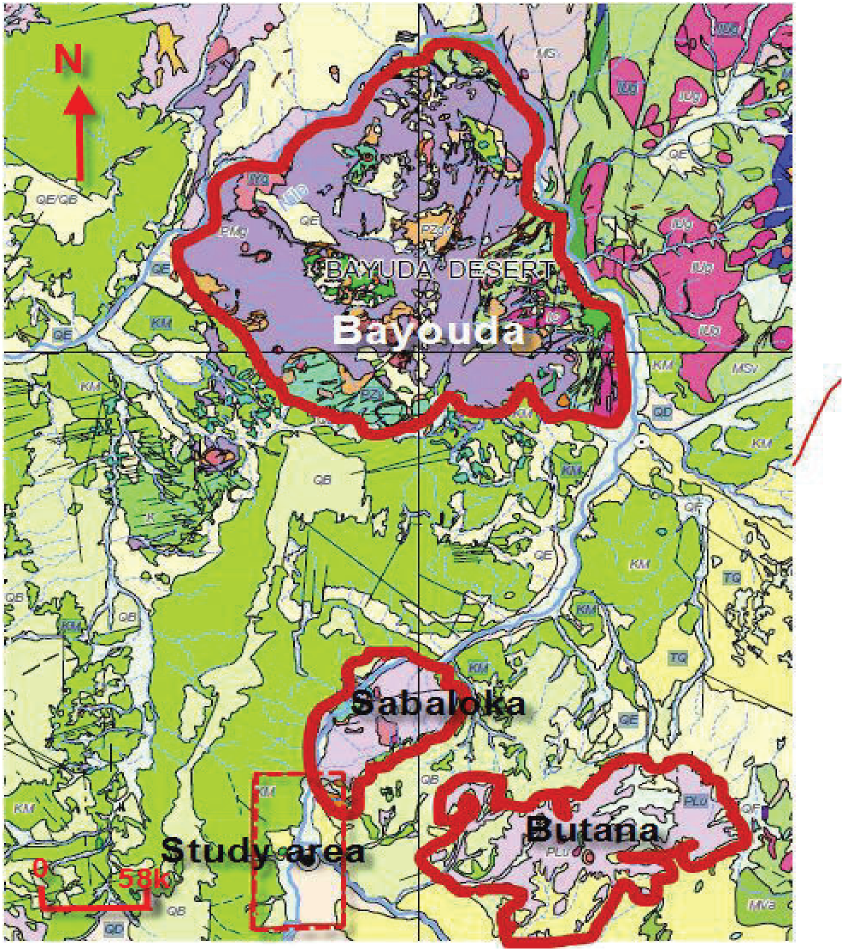

Fig 3. Location of the study area, and nearby basement complex, after final geological map of Sudan by Geological Research Authority of Sudan 2016.

QD — QD: Older alluviums, raised terraces, younger gravel and sand plains

QB — QB: Palaeolevees, old gravel and stabilized dunes

CZba: Basalts

CZsy — CZgr: Granites

Cretaceous K — KM — KM: Fluviatile sandstone, lacustrine siltstone and mudstone

Pan-African (Sensu-lato) ensimatic arc assemblage; Igneous
IY: Younger intrusions, IYg: granite, IYs: syenite, IYb: gabbro

PLu/PLt/PLg — **Lower Proterozoic remobilized ensialic continental basement rocks**
PLu: Undifferentiated metamorphic rocks, PLt : Migmatite, PLg: Gneiss

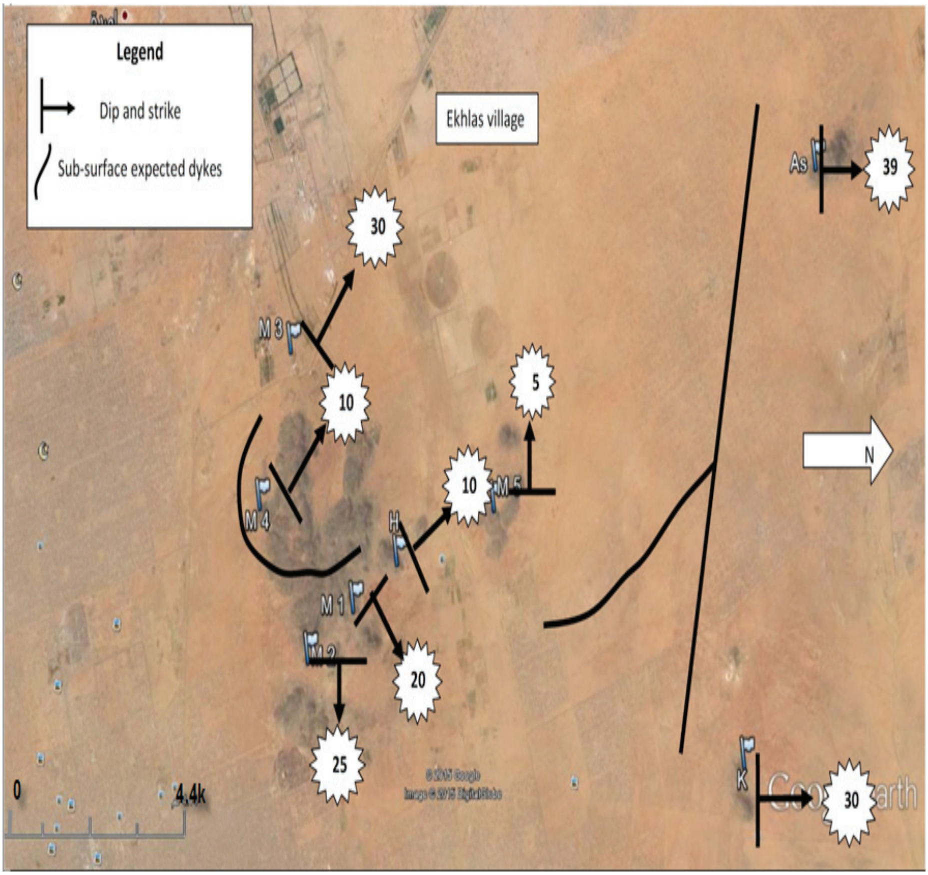

Fig. 4. Strikes and dips of uplifted area.

Discussion

The sedimentary basin in northern area J. Rawyan and J. Shaikh Attayeb (Fig. 2) had been subjected to increasing of PH values, rising of temperature or both of them, whereas outcrops in central and southern of the study area (argillaceous and ferruginous sandstones) have been deposited in different sedimentary basin, i.e. cementation in the northern part of the study area took place in a sedimentary basin characterized by silica mobility, where rapid silica precipitation takes place, chalcedony and opal are the dominant phases. This is the case of hydrothermally mobilized SiO_2 in areas of siliceous hot spring or near contacts of sandstone with volcanic bodies [17]. Silica concentration in basin solution is emphasized by presence of silicified woods at Jebel Shaikh Attayeb [18], and presence of some localities of Hudi chert formation west and south-west of Shendi, and west of the River Nile [19], this concentration of silica in basin solution may refer to adjacent basement complex acidic rocks in Sabaloka inlier, Butana and Bayouda (Fig. 3). The phenomenon of siliceous sandstones is applied to Nubian sandstones north and northwest of Sabaloka basement complex (paleocurrent directions). Tension joints together with difference in degrees and directions of dips suggesting uplift in the center of the study area, this uplift may be attributed to intrusion of Late-Tertiary basaltic rocks into Nubian Formation that have been cropped out at some localities such as J. Turiya and J. Glude (Fig. 1). Relative low values of compressive strength and rebound readings of central and southern outcrops of the study area are attributed to high content of clay and tension joints.

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