New Structural Geological Input from the Barmer Basin, Rajasthan (India)

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Abstract This study is focused on field structures especially on different brittle structures such as P- and Y-planes, normal faults and reverse faults in the eastern, western and the northern parts of the Barmer basin, Rajasthan (India). Besides aforesaid structures, basalt dykes are mapped in the northern and in the eastern parts of the basin. Reverse faults are first time documented with top-to-NNW shear in the Malani Igneous Suite (MIS). Shear sense indicator are preserved in sandstones with top-to-NE slip. The eastern part of the Barmer basin was affected by NE–SW extension and N–S compression. The western part of the basin witnessed oblique-slip faulting with NE–SW trend and can be identified in terms of brecciated zones cemented in calcareous material at several locations. The enigmatic N–S compression in the extensional Barmer basin might be the far-field effect of the India-Eurasia collision, and deserves more studies.

Keywords Barmer basin · P- and Y-planes · Brittle structures · Fault · Extension

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1 Introduction

The Barmer/Barmer—Sanchor basin is located in western Rajasthan, with an area of ~11000 km^2. This basin is ~200 km long and 40 km wide with estimated depth of 6 km. The basin is surrounded by the Bikaner–Nagaur basin in NE and Jaisalmer basin in N/NNW (Fig. 1). It is the smallest basin in Rajasthan compared to Bikaner–Nagaur basin (70000 km^2) and Jaislmer Basin (45000 km^2). Recently Biswas et al. (2022a, 2022b) provided detail geomorphologic works from Barmer and Jaisalmer,

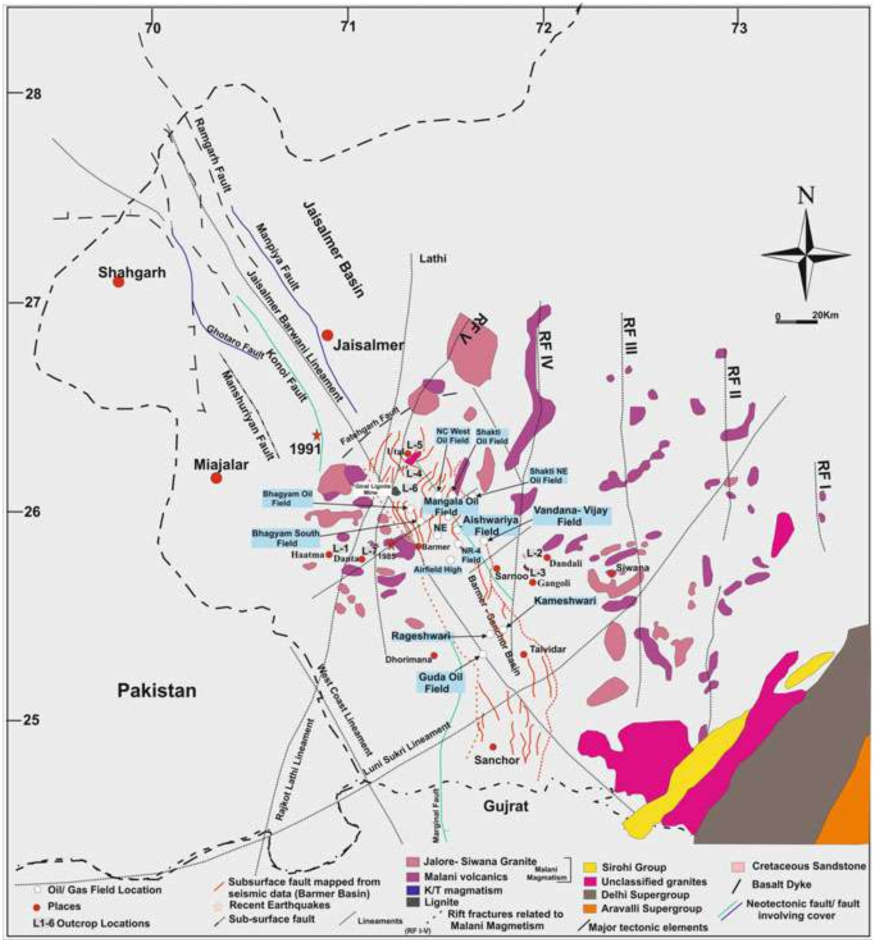

Fig. 1 Geologic map of western Rajasthan is showing the Barmer–Sanchor basin along with different tectonic structures (modified from Dasgupta & Mukherjee, 2017). Field outcrop locations are marked on the map

respectively, basins from western Rajasthan. Kar et al. (2022) has produced detail organic geochemical results from a lignite mine from Barmer. Haldar et al. (2022) has presented detail architecture of Kiradu temple located in Barmer area.

Barmer basin formed a graben structure due to the breakup of Indian craton in Late Cretaceous (Dutta, 1983; Mathur & Kumar, 2003; Dolson et al., 2015; Dasgupta & Mukherjee, 2017). This area is poorly understood in terms of surface geology due to the vast sand cover (Das Gupta, 1974; Sisodia & Singh, 2000). Dasgupta and Mukherjee (2017) added some new surface structural data in the Barmer basin to understand the geology of the area. Detail surface geological data are still lacking in the region and researchers depend more on the geophysical data.

This work presents new field structural data from the Barmer basin and enhances the knowledge of the rift formation.

2 Geology

Precambrian Malani Igneous Suite (MIS) constitutes the basement of the Barmer basin (Pareek, 1981; Bladon et al., 2015; Compton, 2015; Dasgupta & Mukherjee, 2017). Lathi Formation of Jurassic age rests over the MIS in the northern portion of Barmer basin near the Fatehgarh ridge (Fig. 1). Fatehgarh ridge is well exposed on the Barmer-Jaisalmer highway near Location-4 (Utal village). The Mesozoic Ghaggar Hakra Formation is well exposed near Sarnoo hills (Sisodia & Singh, 2000; Dolson et al., 2015; Dasgupta & Mukherjee, 2017). There are numerous basalt dykes intrusions (Figs. 1, 4, & 5) in northern and eastern portions of the basin. Some authors correlate these intrusions to the Deccan volcanism (Chandrasekaran et al., 1990; Basu et al., 1993; Sen et al., 2012; Dasgupta & Mukherjee, 2017).

Previous researchers marked these igneous activities in the eastern part of the basin but this study mapped new locations of the dykes in northern part of the basin as well (Fig. 1). Barmer and Fatehgarh Formations are the source of Bhagyam, NC west, Shakti, Mangla, Aishwarya, Vandana, NR-4, Kameshwari, Rageshwari and Guda oil fields (Farrimond et al., 2015; Lobo et al., 2015; Shiju et al., 2008) (Fig. 1).

The basin is situated at the western portion of the Aravalli range. This is the shelf-part of the Paleo-Tethys of the Gondwana period (review in Dasgupta & Mukherjee, 2017). Southern part of Barmer basin rifted into two parts: first NW–SE extension due to the east west Gondwana breakup in Mesozoic age and second NE–SW extension due to the Seychelles microcontinent breakup from India (Sharma, 2007; Collier et al., 2008; Mishra, 2011; Torsvik et al., 2013; Bladon et al., 2014, 2015; Dasgupta & Mukherjee, 2017). Devikot-Fatehgarh fault marks the northern boundary of Barmer basin, which formed due to the Himalayan collision during Late Tertiary (Compton, 2009; Mukherjee & Koyi, 2010a, 2010b; van Hinsbergen et al., 2012; Mukherjee, 2013, 2015; Mukherjee et al., 2013, 2015; Kelly et al., 2014; Dasgupta & Mukherjee, 2017).

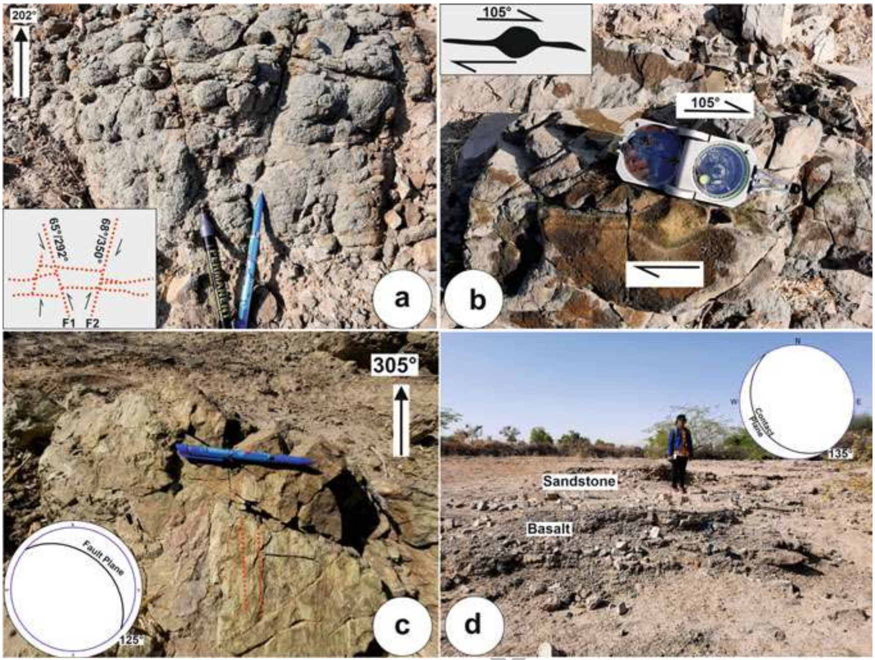

Fig. 2 Field photographs of location-2 along the Luni river Dandali village. **a** conjugate strike slip faults, movement can be depicted along the quartz veins (along fault plane F1 dipping 65° towards NW-292° and F2 fault dips at 68° towards 350°) in basalt, observed on horizontal plane; **b** asymmetric boudin in sandstone shows slip towards 105°, observed on horizontal plane; **c** sub-vertical fault striation shows down dip movement on a plane that dips 40° towards NE (040°); **d** a gently dipping (25°) conformable contact between sandstone and underlying basalt at the right bank of Luni River near Dandali village (Fig. 1)

3 Fieldwork and Discussions

The Barmer basin can be divided into eastern domain (Barmer to Siwana), western domain (between Barmer and Miajalar) and northern domain (Barmer to Fatehgarh Fault) (Fig. 1).The basaltic eastern domain belongs to MIS (Fig. 2a), sandstone of Fatehgarh Formation (Fig. 2b, c and d) and Eranpura granite or unclassified granite (Fig. 3). This domain is studied in Luni river section and Dandali village in the eastern part of Barmer city. The faults and shear sense indicator of the eastern domain are dominated by reverse faulting with top-to-NNW slip (Fig. 2). Basalt of MIS shows conjugate strike slip faulting with sinistral and dextral movements (Fig. 2a). Asymmetric boudins in sandstone show top-to-NE slip (Fig. 2b). Fault plane trend in sandstone is NW–SE: and display up-dip movement (Fig. 2c). The contact between underlying MIS to the overlying Fatehgarh Formation sandstone is conformable and almost parallel to each other with NW–SE trend, dips gently ~10–15° towards SW (Fig. 2d).The granite hills near Gangoli village (Fig. 1) in eastern Barmer basin are intruded by basalt dykes with NE–SW trend (Fig. 3a,b). Some fault planes are also observed in the granite with strike-slip nature (with NW 315° trend). Granite of this area is non foliated, grey in colour and has porphyroclasts of feldspar. This study shows that eastern domain of Barmer basin has witnesses of two stress regimes: NE–SW extension and N–S compression.

The basalt in western domain is highly deformed by brittle fracture and is foliated locally (Fig. 4). The general foliation trend of basalt is ~N–S with moderately dip (38°) towardsN 275°.

Oblique faults are dominated in this area with NE trend (plunge-080°, trend-064°) (Fig. 4a and b). At one location near the Daanta bus stop (Fig. 1) strike-slip fault is observed with trend NW–SE, which dip steeply (81°) and show dextral slip (Fig. 5). Fault breccia and calcareous materials are observed along these fault planes (Fig. 4c). This is new field structural data from the western margin of the Barmer basin.

Here, one more episode of deformation is observed in the form of P and Y brittle shear planes. The N–S trending faults are common in western domain. Near Haatma and Kiradu temple, N–S trending faults (P-planes) terminate against the NW–SE trending faults (Y-planes) (Fig. 6a, b). They show top to NW slip in the foliated basalt of MIS (Fig. 6a, b).

Fig. 3 Field photographs of location 3, near Dandali and Gangoli villages: **a** Google Earth image of the location shows the exposures of porphyritic grey granite and later intruded basalt dykes; **b** exposure of the basalt dyke into the greyish colour granite. The dyke trends 060–240°

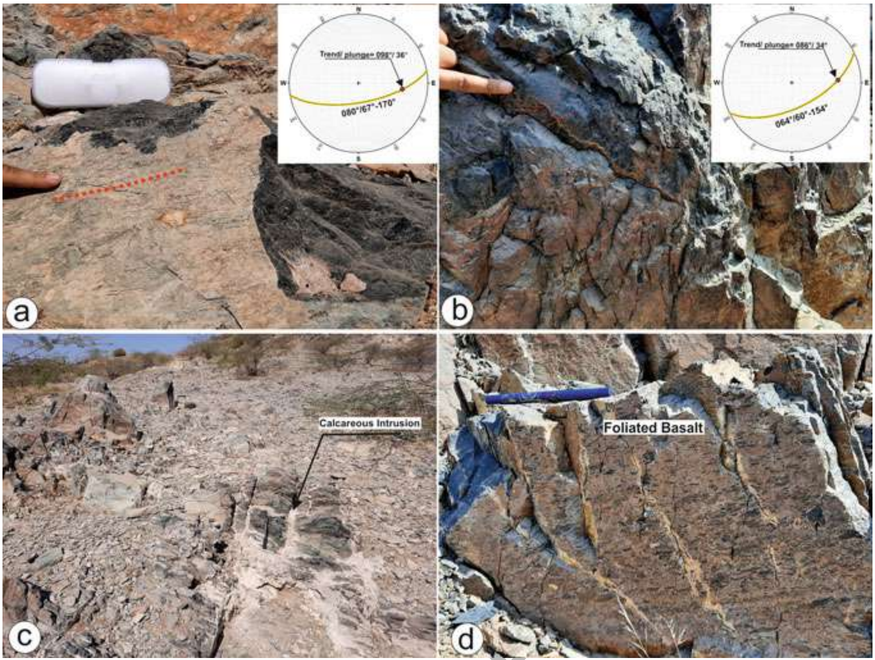

Fig. 4 Field photographs of location-1 near the 32 km milestone of Barmer adjacent to the Haatma village (Fig. 1): **a**, **b** slickensides are observed on NE–SW trending fault surfaces; **a** fault surface with slickensides step-like elevations (rake 40°) shows slip towards 087° (strike 080°; dip 67° and dip direction 170°); **b** fault surface show oblique movement with 086° trend and 34° plunge; **c** basalt exposure show calcareous intrusion. Part of pen (~11cm) as scale. **d** Basalt shows well developed foliation with strike 185°, dip 38° and dip direction 275°. Pen (~12cm) shown as scale

The northern domain of the study area lies between Barmer and Fatehgarh fault and is well exposed on Barmer–Jaisalmer highway (National Highway 70). There is conglomerate bed identified below the Fathehgarh Formation sandstone (Fig. 7a). This conglomerate bed represents unconformable contact between MIS and Fathehgarh Formation in the region. The Fathegarh Formation shows E–W trend with gently dip of 24° towards south (Fig. 7b). Fatehgarh sandstone is intruded by later igneous activity in terms of basalt dykes (Fig. 8a). The trend of the dykes is NE–SW and intersects the strike of sandstone at an acute angle (Fig. 8a,b). The basalt dykes show chilled margin and parallel or longitudinal joint with NE trend. Transverse joints are developed in the dykes with 320° trend (Fig. 8c). Basalt dykes show sigmoid brittle planes or the P-planes that are associated also with tangential Y-planes (Fig. 8d). The Y-plane trends 235° SW (80° dip towards 145°) and P-plane trends 325°NW (80° dip towards 055°).

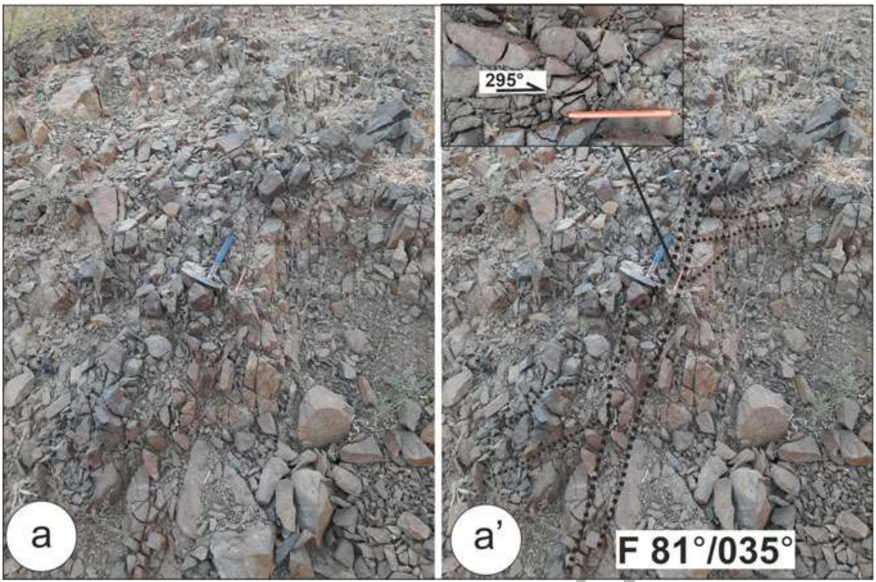

Fig. 5 Field photographs of location 7, near Danta bus stand, 1.5 km before of Haatma village towards Barmer: original (**a**) and with interpretation (**a**') exposure of basalt shows dextral fault with clearly visible curved fracture and curved surfaces on sub horizontal surface. The trend of the fault is 125° (SE) with 81° dip amount and dip direction of 035° (NE). Geological hammer (30 cm) as scale

4 Conclusions

The studied area can be divided into three domains based on the structural data.

- Eastern domain of Barmer basin: This place has witnesses of two stress regimes, NE–SW extension and N–S compression.
- The basalt in the western domain is highly deformed by brittle fractures and at some locations it is foliated. Oblique-slip faults are dominated in this area; attitude of slip direction: 080° plunge, 064° trend. Infrequent strike-slip faults (trend NW–SE with dip amount 81°) occur alongwith breccia and calcareous cements. This is new data from the western margin of the Barmer basin.
- In the northern margin, conglomerate bed has been identified below the Fathehgarh Formation sandstone. This bed represents unconformable contact between MIS and Fathehgarh Formation. Fatehgarh sandstone is intruded be later igneous activity in the form of NE–SW trending basalt dykes.

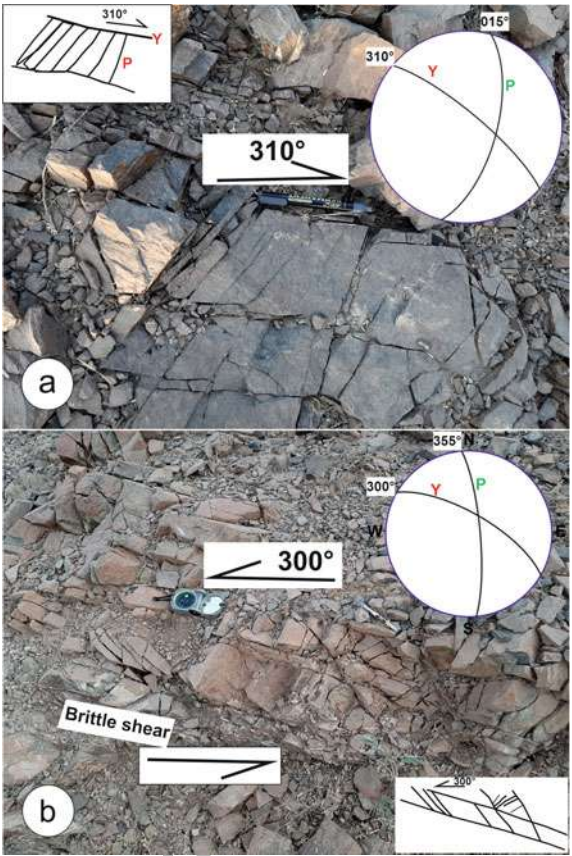

Fig. 6 Field photographs of location-7 near Danta bus stand 1.5 km before of Haatma village towards Barmer; **a** exposure shows sinistral brittle shear within basalt, observed on a horizontal plane. The Y-plane trends NW (dip amount 70° and dipping towards NE) and P-planes trend NE (75° dip towards SE); **b** two brittle shear intersecting the basalt (one along brunton compass and second along pen 12 cm long). The Y-plane trends NW (300°) (dip amount 70° and dipping towards NE) and P-planes trend NNW (dip amount 85° and dipping towards E). Brunton compass (18 cm) as scale

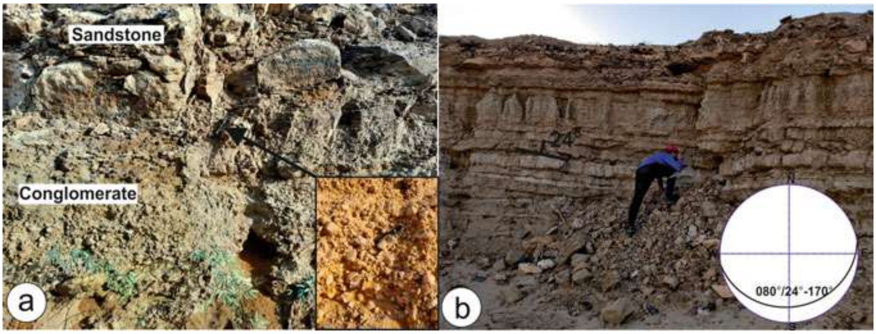

Fig. 7 Field snaps of location-4 near Utal villages near wind mill no-NGB0054U124: **a** a conglomerate bed below sandstone with 1–2 m thickness. Pen (~12 cm) as a scale. **b** Sandstone beds with NE–SW trend and 24° dip towards SE (170°)

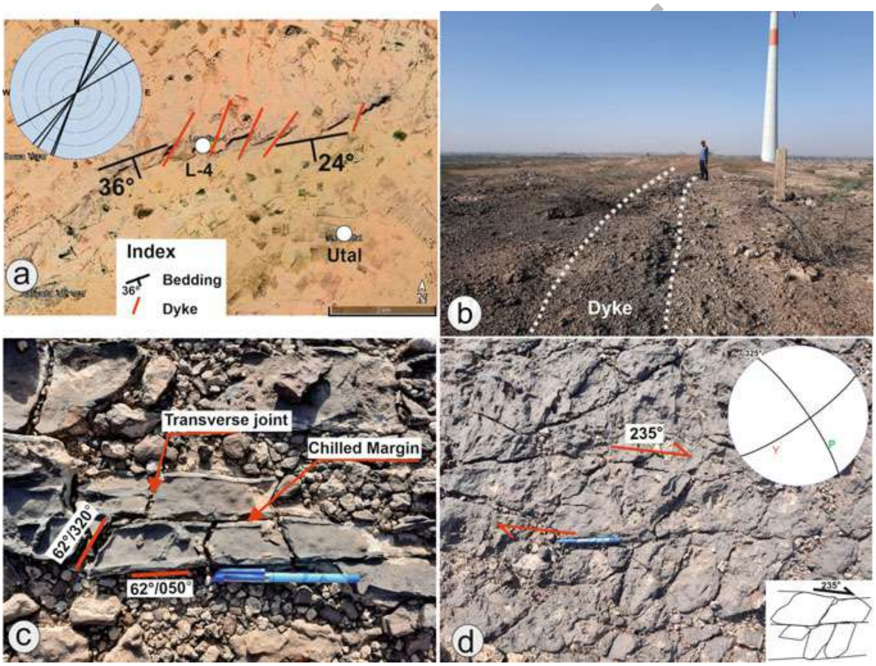

Fig. 8 Field photographs of location-4 near Utal villages: **a** Google Earth image of the location-4 shows the exposures of sandstone and later intruded basalt dykes. Bedding attitude and dyke orientation (NE–SW trend) shown; **b** trend of a dyke in front of the wind mill no-NGB0054U124 is 020–200°, thickness of the dyke is varies from 0.5 to 1.5 m; **c** transverse fractures (dip/dip direction: 62°/320°) and longitudinal joints (dip/dip direction: 62°/050°) with chilled margin. **d** Dextral brittle shear with Y- and P-planes within basalt dyke, observed on horizontal plane. The Y-plane trends 235° SW (80° dip towards 145°) and P-plane trends 325°NW (80° dip towards 055°). Pen (~11cm) as a scale

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