co-workers' study does not explicitly answer the question of whether all the marginal lands identified as suitable for biofuel production could be used without harming biodiversity and the environment. Moreover, land that is fallow today might be needed in the future for agricultural production, to offset the demands of the world's growing population.

Another question raised by the study concerns greenhouse-gas mitigation: for the biofuel-cropping systems under consideration, the authors found that, apart from fossil-fuel offset credits, increases in soil-carbon stocks are the major driver of climate benefits. But the rate of increase of soil-carbon stocks will slow down with time, so that the stocks reach an equilibrium level within a few decades[10]. It therefore seems that comprehensive assessments of the long-term climate impacts of biofuels will require the quantification of spatially and temporally explicit soil-carbon sequestration potentials. ■

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SOLAR PHYSICS

Towards ever smaller length scales

Determining the real scale of structures in the Sun's corona has proved difficult because of limited spatial resolution. Now high-resolution imaging has allowed dynamic structures on scales of 150 kilometres to be observed. **SEE LETTER P.501**

PETER CARGILL

The origin of the Sun's outer atmosphere, the corona, is a long-standing scientific problem of great interest and complexity. Why does a star with a surface temperature of roughly 5,700 kelvin have an outer atmosphere with temperatures in excess of 1 megakelvin, and why does the corona exhibit phenomena such as flares? The answer lies in the energy contained in the Sun's magnetic field, which fills the corona, as inferred from coronal images at extreme ultraviolet and X-ray wavelengths. How the magnetic energy is dissipated in the corona and sustains its temperature is controversial, but comes down to a determination of the spatial scales of coronal structures. On page 501 of this issue, Cirtain *et al.*[1] identify dynamic structures on scales of 150 kilometres, which represents a major constraint that theories must now confront.

Before 2012, the best spatial resolution of the solar corona was obtained by NASA's Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory spacecraft, which was launched in 2010. The instrument resolves scales of about 900 km and looks at several wavelength ranges corresponding to different temperatures. However, images of the visible solar surface at a resolution of 100 km show distinct magnetic and plasma structures, and so the question arises as to whether structures with these scales are also present in the corona.

In their study, Cirtain *et al.* used the High-resolution Coronal Imager (Hi-C), a new extreme-ultraviolet instrument that was launched on a rocket on 11 July 2012 and obtained roughly 5 minutes of data before re-entering Earth's atmosphere. The instrument looks at coronal plasma with temperatures of around 1.5 MK, and is capable of spatial resolution at least five times better than the AIA: the Hi-C can resolve scales on the order of 150 km. To place this in context, it took more than 30 years to improve the spatial resolution from the few thousand kilometres obtained by instruments on NASA's Skylab observatory to that obtained with the AIA. The Hi-C instrumentation performed up to expectation, and images of the Sun show unambiguous structure at the desired resolution — a huge achievement.

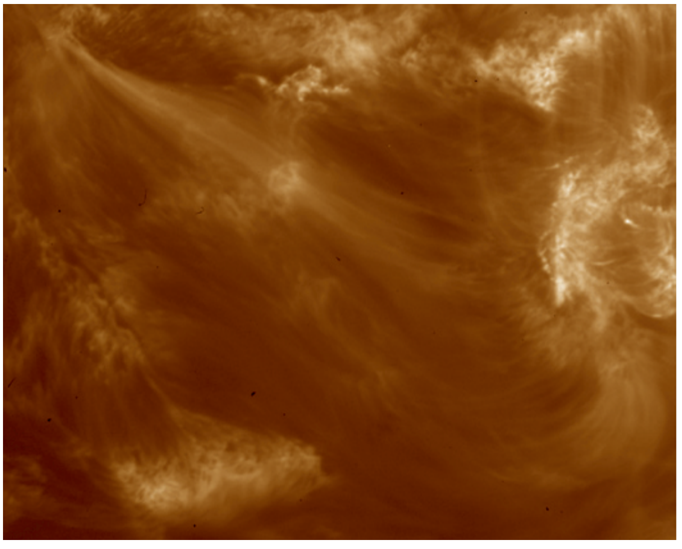

Figure 1 | Small structure in the corona. The image is a sub-field of the entire field of view observed by the High-resolution Coronal Imager (Hi-C) and analysed by Cirtain and colleagues[1]. It shows the solar corona at a temperature of roughly 1.5 megakelvin over a dimension of 154.6 × 123.7 arcseconds, or 112,000 × 90,000 km. The strands running from top left to lower right are believed to outline the magnetic field in the corona, as are the other structures in the image. The remarkably fine structure is visible everywhere and constitutes the major advance achieved with the Hi-C. (Image prepared by J. Cirtain and A. Winebarger.)

A striking feature of Cirtain and colleagues' results is the dynamic structures visible at the limit of resolution, clearly evident by comparing images from the Hi-C and AIA in the paper's Supplementary Videos 1 and 2 (ref. 1). (The reader should also look at other aspects of the videos to note how much else is happening on these small scales, as is also evident in Fig. 1.) The dynamic behaviour of the observed structures is interpreted as evidence for 'magnetic braiding', an effect in which small bundles of magnetic field become wrapped around each other owing to plasma motions at the solar surface[2]. Whether this is in fact the case is unclear, but there seems little doubt that magnetic-field dissipation on a fundamental scale is seen, with different field elements interacting with one another through magnetic reconnection[3], a process that changes the magnetic-field topology through dissipation of electric currents. To me, the Hi-C images are reminiscent of computational models of the kink instability, a process known from plasma physics that is also thought to occur in the corona[4]. Although such processes have long been conjectured, prima facie evidence for coronal reconnection, as found by Hi-C, is an important result.

A more general point concerns the very presence of structures at this resolution. There has long been a debate about when coronal structures are resolved; that is, what is an elemental structure? In the past, some have stated that structures seen by earlier solar missions are resolved, or 'monolithic'. Others have argued from theory and interpretation of data[5–7] that scales on the order of 100 km were to be expected, and that such high resolution was needed. Indirect evidence from the AIA had also begun to point the way to such scales[8], but the Hi-C results show that any debate on the structure of the corona now needs to address scales of 100–200 km or smaller, as can be seen in Figure 1.

Clearly, even in 5 minutes of observations there is a wealth of data that need to be analysed. The next stage is securing Hi-C, or an instrument with similar or improved performance, on an orbiting spacecraft. This spacecraft must also carry a modern extreme-ultraviolet spectrometer[9] — both to complement Hi-C and to provide fundamental plasma measurements of density, temperature, velocities and small-scale turbulence — as well as an instrument capable of measuring signatures of energetic particles, which are known to be a significant product of the magnetic-reconnection process[10]. Only with such complete instrumentation can a proper understanding of coronal structures be attained.

Has Hi-C really resolved the corona? To do this will require observation of a wider range of solar conditions than is feasible in a short rocket flight, and one should not bet against the existence of further fine structure within the scales detected by Hi-C. But for those who have wanted to see observations on such scales for decades, there is a feeling that things are getting interesting, and quantitative tests of competing theoretical ideas can be undertaken, as is evident from the above discussion of this short data set. ■

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PALAEONTOLOGY

Gritting their teeth

A comparison of the wearing effect of plant-derived silica and desert dust on tooth enamel suggests that extreme wear on teeth might not be caused by food. The findings may change some thoughts about the diets of human ancestors.

BERNARD WOOD

Chewing is much like using a pestle and mortar, but upside down. Your jaw muscles supply the power and move your lower teeth (the pestle) up and across your upper teeth (the mortar). As long as any food caught between them is not especially hard or tough, it will be broken into smaller pieces and the teeth should remain intact. But, unlike the granite or marble pestle and mortar in your kitchen, teeth are gradually worn down. It has been widely assumed that interactions with food are the cause of this destructive damage. But, writing in the *Journal of the Royal Society Interface*, Lucas *et al.* suggest[1] that the culprit may not be the food we chew, but the dust or grit we ingest along with it.

When teeth are newly erupted into the jaw, the enamel surface is relatively pristine. However, even though enamel is the hardest tissue in the body, once teeth have been used to chew on food, tiny grooves, scratches and pits soon pockmark the enamel. Living animals with different diets produce different patterns of dental microwear[2,3], so it was natural to assume that these patterns can be used to infer the types of food eaten by our ancestors and close evolutionary relatives[4]. However, a consideration of the physical processes that cause wear to hard surfaces calls some of these assumptions into question.

MUSEUM AND HOUSE OF CULTURE, DAR ES SALAAM

Figure 1 | Signs of wear. The fossilized palate and maxillary teeth, seen from below, of OH 5, the type specimen of *Paranthropus boisei*, an archaic hominin (human ancestors and close relatives) that lived approximately 2 million years ago. The species is referred to as a hypermegadont, meaning that it has large, broad cheek teeth and small front teeth. Although OH 5 was not yet an adult, the enamel on the grinding faces of both first molars (M1), the premolars (P4 and P3) and the canines (C) has been worn down to expose the softer dentine in the pulp cavities of the teeth (examples of wear are indicated by arrows). Lucas *et al.*[1] suggest that only grit, not food, is hard enough to have removed the exceptionally thick enamel covering of these teeth so quickly.