age of a highly cross-linked gel was minor, but the weakly cross-linked gel underwent large volume changes when the temperature was varied. The UV light exposure was performed with a patterned mask of micrometer-sized opaque dots with varying diameter. This process "printed" regions on the sheets that shrank a lot (opaque dots, weakly cross-linked regions) or a little (UV-exposed, highly cross-linked regions). Regions containing large dots tended to shrink more than those with small dots, and as long as the sheet was not too thin, this discrete "print" was converted into sheets that underwent smooth, nonuniform swelling.

Several preprogrammed geometrical shapes were created this way, and the authors performed the nontrivial tasks of calculating swelling profiles, producing the NEPs, and measuring the shapes of gel discs a few hundred micrometers in diameter. Even on such a small scale, the authors showed impressive quantitative agreement between experiments and theoretical predictions. In this sense, shaping by active deformation can be regarded as an existing design technique on the submillimeter scale.

Shaping of NEPs has some distinctive characteristics. First, a 2D printed "picture" is converted into a 3D shape; the figure shows centimeter-scale NEP discs made of selectively cross-linked NIPAm gel, along with the masks that were used for their production. The conversion of mask's local gray levels into swelling ratios and finally into 3D shapes shows how the connection between the "picture" and the "shape" of a sheet is often surprising. Some very simple masks create complex 3D shapes. In addition, this method only sets lateral reference lengths, which may correspond to several different surfaces and hence shapes. A configuration of a NEP is selected from many possible ones that have relatively small energetic differences. As a result, NEPs show extraordinary responsiveness; they easily undergo shape changes between very different configurations as a result of small changes in parameters. This property might be desired in biomechanics and industrial design.

In principle, NEPs can be constructed from other materials, such as nematic elastomers and electroactive polymers. The underlying geometrical principles that govern shaping by active deformation are possibly relevant on a nanometer scale for use with self-assembled supramolecular structures. This broad relevance is likely to motivate the development of software packages that will allow convenient study and design of shape-transforming sheets. Finally, the physics of shaping by active deformation allows for a better understanding of naturally occurring systems, such as invertebrate's motion and morphogenesis during growth (*4*).

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ECOLOGY

The Human Factor

Marine sediments suggest that climate was not the sole driver of the African rainforest crisis 3000 years ago.

Lydie Dupont

How did early farming cultures affect the surrounding vegetation? Did their activities disturb the forest beyond their fields, or was their land use compatible with natural developments? On page 1219 of this issue, Bayon *et al*. (*1*) report an important step toward answering this question by showing that climatic changes alone cannot explain the vegetation changes that occurred in West Central Africa between 2000 and 3000 years ago.

Linguistic analyses of Bantu languages suggest that Bantu-speaking peoples expanded from their homelands in eastern Nigeria southward and eastward during the first millennium B.C.E. (*2*). Although there are not many relevant archaeological sites, evidence from Cameroon, Gabon, and Congo supports the interpretation that this expansion involved agriculturists who brought iron-smelting technologies with them. For instance, the earliest pottery of the Congo basin, dated ~400 B.C.E., is found in its western part along tributaries of the Congo River (see the figure). This pottery style is associated with those of Iron Age cultures in Cameroon. Analysis of the pottery style development indicates migration and expansion along the larger tributaries of the Congo River during the following centuries (*3*). The impact of these people and their expansion on the surrounding vegetation is difficult to discern, because pollen records do not provide unambiguous indicators of human versus climatic effects on the forest.

During the first millennium B.C.E., extensive changes took place in the rainforest of West Central Africa. Numerous pollen records suggest that the mature rainforest was replaced by a lighter type of forest with more pioneer trees, a forest adapted to a drier or longer dry season, or savannah vegetation (see the figure) (*4*). This "rainforest crisis" has been widely attributed to climate change alone, laying the blame for the forest changes on decreased precipitation and a longer dry season (*5*–*7*).

In northern Africa, a trend to drier conditions started roughly 5000 years ago (*8*); over the course of the next ~2000 years, this drier climate extended south into Central Africa (*9*). However, 3000 to 2000 years ago, the mature rainforest declined even more than during the period of the Last Glacial Maximum between 17,000 and 24,000 years ago, when climatic conditions around the world were drastically different from those seen in the past 10,000 years (*10*). The extensive rainforest changes between 2000 and 3000 years ago are difficult to reconcile with moderate changes in climate in West Central Africa at this time, as indicated by biogeochemical proxies of continental temperature and precipitation (*11*).

Bayon *et al*. show that the rainforest crisis involved more than aridification and increased seasonality. Using marine sediments deposited in front of the mouth of the Congo River, they measured two proxies for the weathering of rocks for the time period from 20,000 to 2000 years ago.

First, they determined the ratio between aluminum (Al) and potassium (K). This ratio depends on both the lithology of the source rock and the degree of chemical weathering. Chemical weathering is high under warm, wet conditions. Hence, Al/K ratios are higher in clays from rivers draining warm tropical areas than in those from colder and/or drier environments. Al/K ratios in marine sediments off the Congo River normally covary

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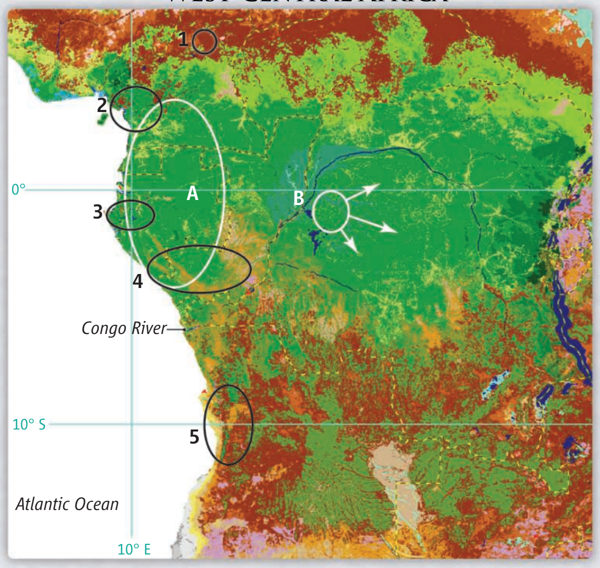
WEST CENTRAL AFRICA



1 ~3000 years ago: submontane semideciduous forest changes to savannah
2 2500 to 2700 years ago: disturbed rainforest, pioneer trees, patches of savannah
3 2500 to 2400 years ago: mature rainforest replaced by secondary forest
4 3000 to 2500 years ago: grasslands extend at swampy and forested sites
5 3700 to 2000 years ago: two-step decrease of forest, extension of savannah

A time of change. Pottery styles from late Neolithic and iron-age cultures nearer the coast (area A) may have been a precursor of the earliest pottery, dated 2500 to 2100 years ago, found in the inner Congo Basin (area B) (*3*). Results reported by Bayon *et al.* suggest that this expansion of agriculturists may have been partly responsible for extensive changes in the rainforest between ~3700 and 2500 years ago (numbers 1 to 5) (*5*–*7*). Satellite-derived vegetation map of Central Africa from (*12*). Forest in green, forest-savannah mosaic in light green, woodland in brown, grassland in yellow, agriculture in pink.

with other proxies for continental temperature and precipitation.

Second, they measured hafnium (Hf) and neodymium (Nd) isotopes. Both the Nd and the Hf isotopic composition of rocks are determined by magmatic processes in the upper continental crust and depend on the rock source, but Hf isotopes are additionally changed by weathering of silicates. By comparing the isotopic composition of these trace elements in marine sediments, changes in silicate weathering can be deduced. Bayon *et al.* find that the Hf isotopic composition was relatively low during the Last Glacial Maximum (~20,000 years ago) and increased during deglaciation, whereas the Nd isotopic composition remained constant.

The results from both weathering proxies can be explained by changing climate, except for the period between 3000 and 2000 years ago. During the African rainforest crisis of the first millennium B.C.E., both proxies show that weathering increased despite reduced precipitation and constant temperatures.

Hence, although climate played a role in the rainforest crisis, it cannot have been the only factor. The explanation may lie with human activities, which may have had a strong impact on the forest through slash-and-burn agriculture and/or cutting trees for iron smelting (*1*). If so, then the next task will be to differentiate the relative impacts of human land-use effects and climatic influences.

The results of Bayon *et al.* also caution against using the tropical forest development of past millennia as a direct indicator of the West African monsoon. The climatic interpretation of the rainforest crisis invokes a shift in the yearly migration pattern of the Intertropical Convergence Zone to explain aridity and seasonality in West Central Africa (*5*–*7*). However, if only part of the forest change is climatically induced, any inferences using this forest decline will overestimate the aridification and increased seasonality of the past 3000 years.

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CELL BIOLOGY

Embryonic Clutch Control

A molecular clutch couples actin-based contractions to changes in cell shape that drive morphogenesis.

William Razzell[1] and Paul Martin[1,2]

All embryos, from worms to humans, are shaped during development by morphogenetic steps that tug, bend, fold, and sculpt epithelial sheets into forms that resemble, or are the precursors of, the final adult structure (*1*). Most of these changes are the consequence of constrictions of the apical surfaces of epithelial cells that are powered by pulsatile contracting cytoskeletal (actomyosin) networks. On page 1232 of this issue, Roh-Johnson *et al.* (*2*) show that, just as in a car where the power of the engine is linked to forward movement by means of a clutch, clutch control is also the rate-limiting step for contracting cells in tissues.

One of the best-studied examples of apical constriction driving morphogenetic episodes is gastrulation in the fly *Drosophila melanogaster*, in which a strip of approximately 1200 epithelial cells buckles inward and invaginates to internalize the presumptive mesoderm of the embryo (*3*). Variations of this process drive gastrulation in all organisms, as well as other morphogenetic events such as neural tube formation in vertebrates (*4*), which gives rise to the brain and spinal cord, and to formation of the optic and otic vesicles, which develop into the human eye and inner ear, respectively (see the figure). Concerted apical constrictions of cells are generated by the assembly and contractility of actomyosin networks composed of myosin II molecules that tug on actin filaments (*5*). These networks are linked to the plasma membrane by adherens junctions, protein complexes that also weld one cell to its neighbor (*6*). Live imag-

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The Human Factor

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