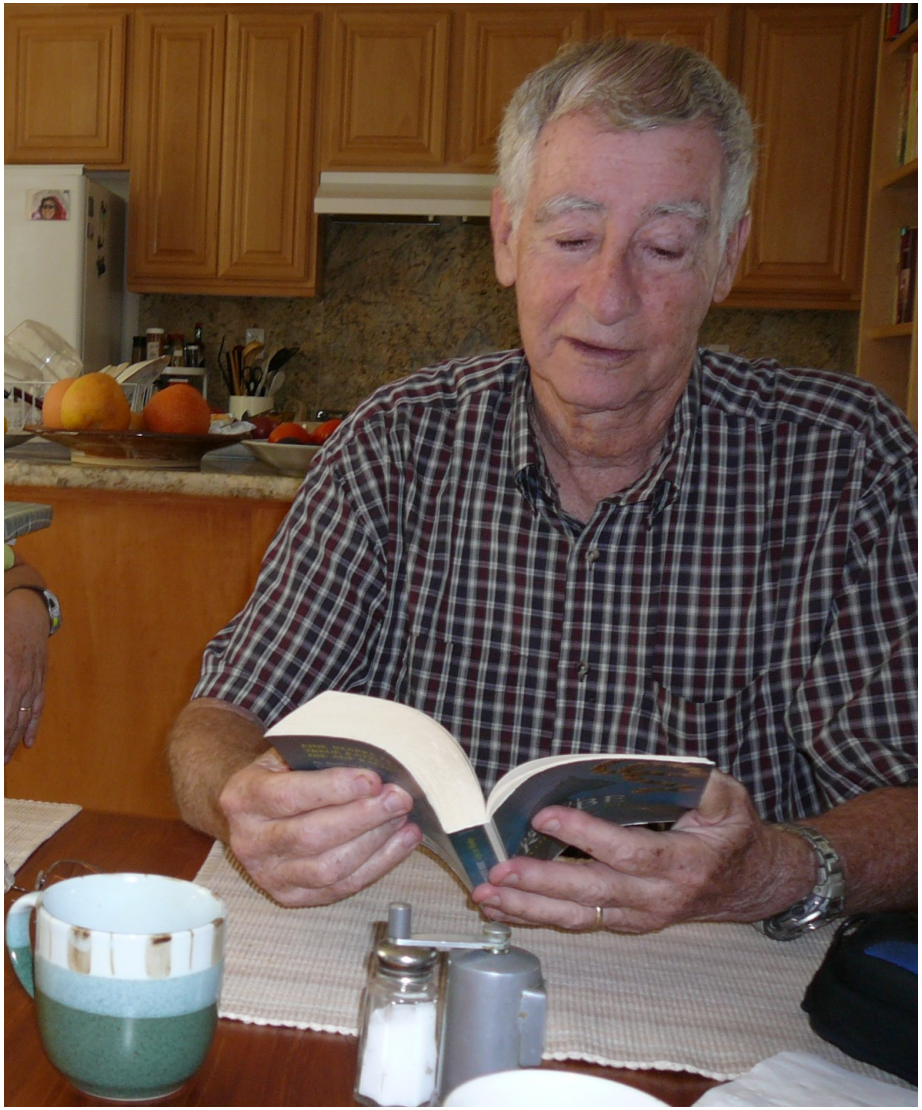
The Puzzling Disks of Crystal Cove



To Richard S. Palais
on the occasion of his 80th birthday.

Dick observed the stone disks on his beachwalks and showed them to his visitors. In his mind they represented a great puzzle which became more intriguing the more one looked. When we saw them again the next year the sense of mystery sprang over.
It took a while to find the right experts.
Dick, we thank you for this exciting scientific adventure.

Traudel and Hermann

Dolomite Concretions
in the Miocene Monterey Formation

When one walks the beach of Crystal Cove State Park one hour south of Los Angeles, one comes to a half mile stretch where curious disk shaped rocks stick out of the sand and the water. Prof. R. S. Palais from UCI has led countless visitors along the beach to these rocks and asked how they could possibly have formed. For several years nobody had a guess.

The problem is, the more carefully one looks the more of a puzzle these rocks are. Most of them stick out of sand or water, which does not lead to further questions. But some of them show their relation to the surrounding rock formation. While the disks show seemingly unperturbed layers orthogonal to the axis of the disks, the surrounding material looks strongly deformed, in some cases, as if the disks were intruders. But then also: the disks and the surrounding material look as if they were exactly the same material. How can such formations arise?

Behind the beach a roughly 100 m high cliff extends for miles. It is made of younger material than the disks and their rock surroundings. Much of the cliff is horizontally layered, but occasionally these layers are strongly perturbed. Was the formation of the stone disks violent or not?

One of Palais' visitors got so intrigued that he started to show the startling pictures around. For example at the California Academy of Science to their questions department. Their answer mentioned *concretions* but was too short to explain the well preserved layers of the disks in their tortured surroundings of the same material. We still could not imagine how these disks could have formed.

But aren't these pictures truely puzzling? Can one give up to search for an answer?

Eventually the pictures were shown to professor Nikolaus Froitzheim, a geologist at Bonn University in Germany. He thought immediately of *concretions* in the miocene Monterey formation, but prefered to consult the library for details.
His initial guess proved to be correct.
But what are concretions and why do they explain these stone disks? Here is Froitzheim's explanation:

Let us begin at a stage where we have unperturbed layered sediments which also contain organic material. In the long process of transformation to stone (diagenesis) at some point the water in the pores between the grains gets saturated with dolomite, $CaMg(CO_3)_2$. The dolomite separates out and hardens the sediment. This hardening does not occur uniformly in the whole sediment, it starts at favourable points and grows concentrically outwards. Concretions, therefore have a round shape, at least initially. The growing of concretions does not visibly perturb the original layers, spherical regions of them harden, this hardening grows concentrically.

Later, further sediment was packed over the above layered material with its round concretions inside. The pressure made the layers thinner, but more so the softer material between the concretions. The concretions themselves became more cylindrical and the original layers got significantly perturbed close to these harder objects and less so further away.

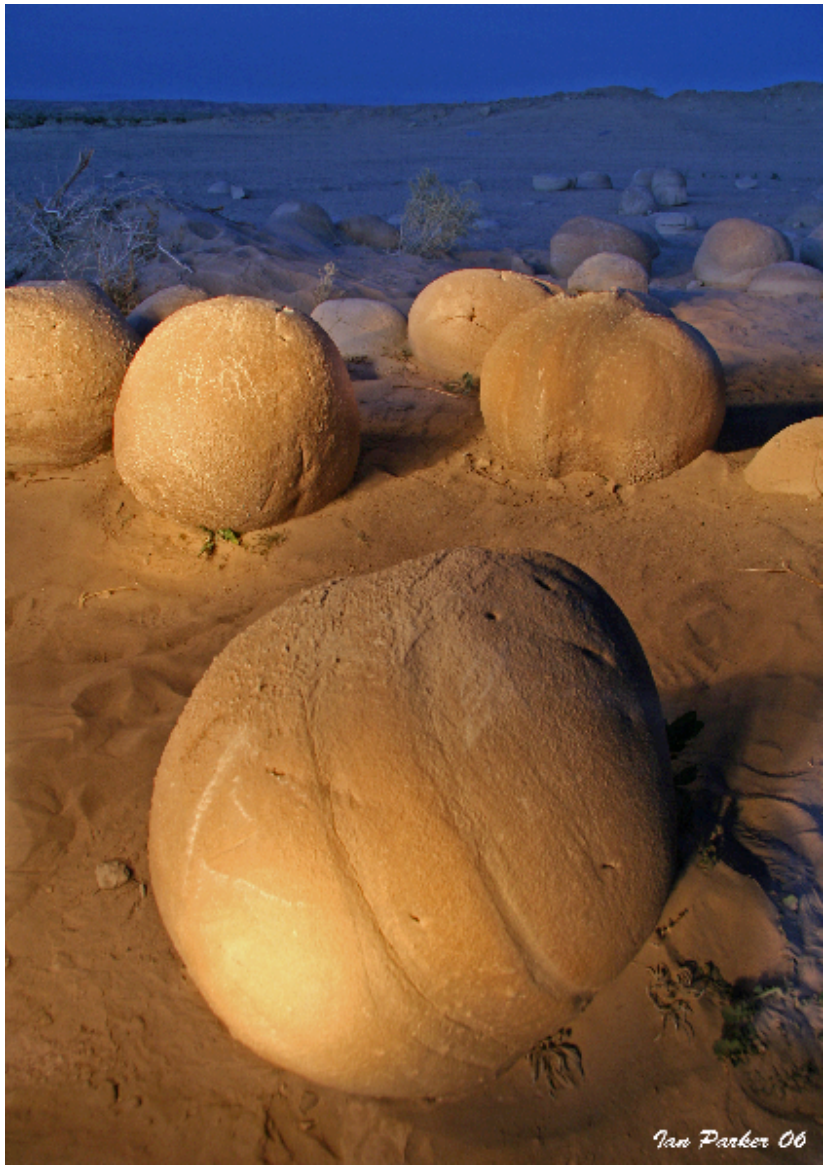
If later some bending of the formation occured then the harder concretions had to be tilted as a whole inside the softer layers. This is visible as an angle between the disk and the outside material.

The geologists say, these layers and their concretions are part of the *miocene Monterey formation*, reaching back from 16 to 6 million years ago, when California was still part of the sea bed. The formation contains many interesting fossils and it is rich in oil. The cliff behind the beach lies above the Monterey formation. In its layers one can also observe concretions. The left picture shows the more pronounced squeezing of the layers outside the concretions in a vertical cross-section. We cannot have such cross section views of the Monterey stone disks. The layered material of the stone disks along the beach survived the squeezing much more intact than these two examples in the cliff:

Note that the further history - after the squeezing - of the Monterey concretions and of their surroundings was the same. In particular the final stone material is determined by the original sediment and therefore the final piece of the puzzle also fits: the concretions and their surroundings are made of the *same* stone material. Recall that the material close to the concretions was most strongly perturbed during the squeezing; it may therefore be weaker and erode more easily, thus helping the concretions to become so intriguingly visible.

In other locations concretions could grow unsqueezed and retain their spherical shape. In such situations it is common that the material which was not reached by the hardening, erodes much faster than the concretions. Therefore beautiful spheres get exposed. We thank Elfi Berndl and Ian Parker for the following examples:

Kettle Point, Ontario, Canada



Pumpkin Patch, Anza Borrego, Cal

Crystal Cove Beach, South View. The concretions are after the curve of the beach.

Crystal Cove Beach, View to North West.

Where are the concretions?

No interest in the Miocene.

Most of them are in sand or water.

Some can be inspected.

Although heavily beaten, this one probably was harder than its surroundings.

Others are still completely enclosed. They must have been squeezed a lot.

If a concretion grew from several nearby centers it was never spherical...

Miocene disks as playground equipment

The cliff concretions have less intact layers than concretions from the Monterey formation.

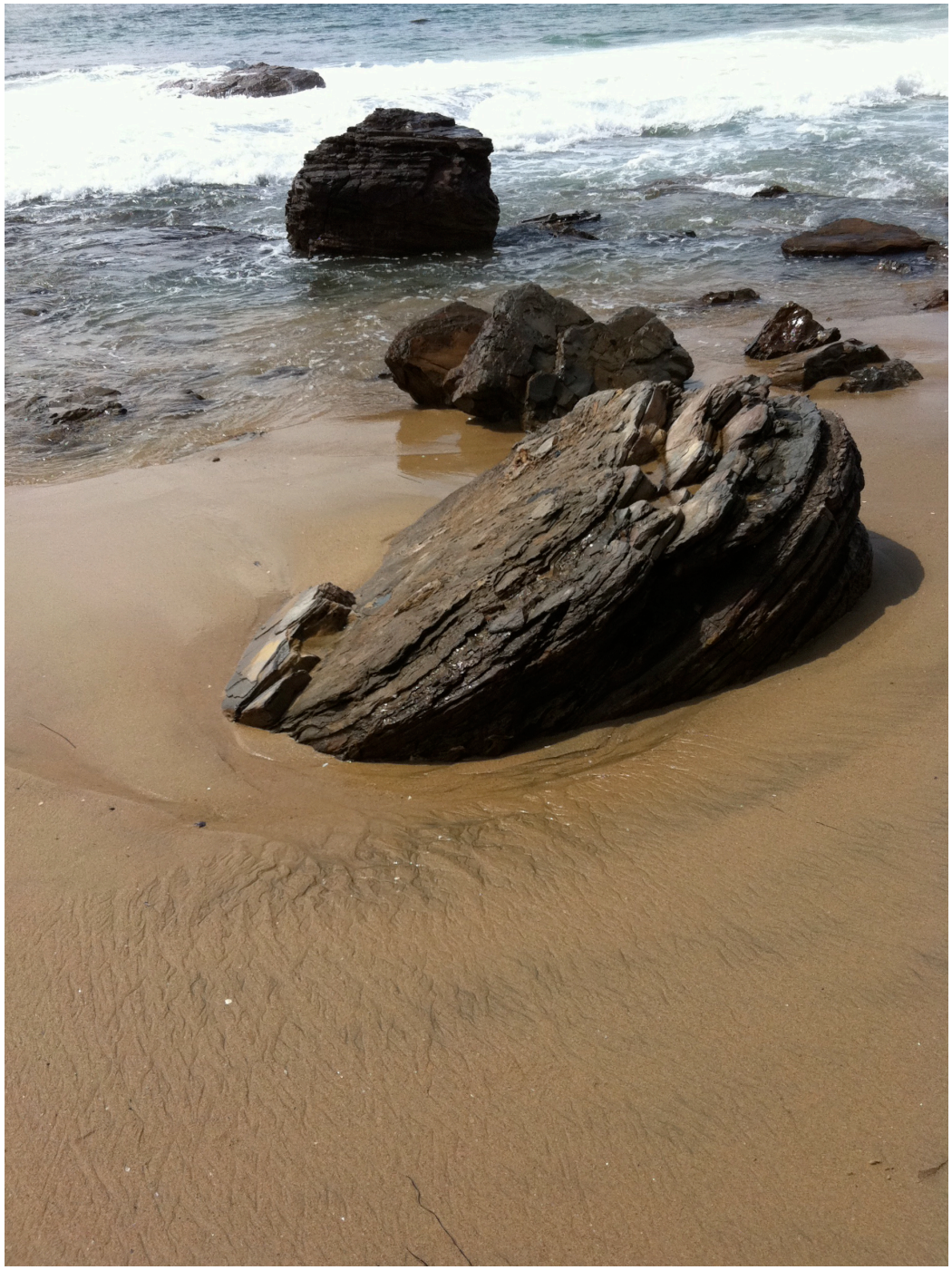
The mostly horizontal layers of the cliff suffered here a violent deformation.

Another cliff concretion with crumbled interior.

The cliff erodes easily.

Admiring the much more resistant Monterey concretions with their well preserved layers.

The concretions resist bending forces and get tilted against the bent surroundings.



Some concretions look very tilted.

Two concretions that started to grow close to each other.

The largest, very flattened example. Against the cliff background.

On Google Earth this concretion can even be seen from the sky.

Pumpkin Patch: More and rounder concretions to be visited in California

Bowling Ball Beach: North of San Francisco, in Mendocino county, you'll find these amazingly round examples.

We thank Ian Parker and Jim Watson for these two beautiful photos.

Walking the beach


University of California, Irvine
Anteater Dr
Bonita Canyon Dr
73
Ford Rd
Turtle Rock Community Park
Shady Canyon
Summit Park
San Joaquin Hills Transportation Corridor (Toll road)
Turtle Ridge
MacArthur Blvd
Newport Coast Dr
Big Canyon Reservoir
San Joaquin Hills
San Joaquin Hills Rd
Signal Peak
Newport Coast
East Coast Hwy
El Camino Real
1
Crystal Cove State Park
Crystal Cove
1 mi