

The Ice Is Gone and the Land Is Still Rising

— At a wavelength of **2000** km the relaxation time is **6152** years, so **19.68** per cent of the depression remains after ten thousand — tripling the wavelength divides the relaxation time by exactly **3** — the cause is gone and the effect continues — [Paper 433]

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— *From thinking to syncing.* —

Abstract

Land in Scandinavia and Canada still rises about a centimetre a year. There is no ice on it now. This paper shows that the effect continues after the cause is gone—and that how long it continues is fixed by numbers. No new theorem or law is claimed. First, the relaxation time is $4\pi\eta/(\rho g\lambda)$, giving **6152** years at a wavelength of 2000 km (Section 2). Second, this is the core of the paper. Ten thousand years after the ice went, **19.68** per cent of the depression remains (Section 3). Third, at the same time **80.32** per cent has already recovered. “Still going” and “only just begun” are different (Section 3). Fourth, tripling the wavelength divides the relaxation time by exactly **3**: a broader load recovers faster (Section 2). Fifth, inverting the remaining fraction returns **10000.000000** years (Section 3). Sixth, the separator is whether something presses now or pressed once (Section 4).

Scope of this paper (scope note): No new theorem or law is claimed—isostasy, post-glacial rebound and the time constant of viscous relaxation are all standard. The Earth’s interior is not settled—a viscosity of 10^{21} Pa s and a density of 3300 kg/m^3 are representative, and variation with depth is not treated. No particular region is discussed—comparing which land is rising by how much is not the subject. The elastic response is not separated—the instantaneous elastic rebound at the moment the ice went is folded into the initial condition. Sea level is not treated—the load of returning water and the deformation of the geoid are not the subject. A single time constant is used—the real response is a superposition of several; the simplest single exponential is used here. Relation to earlier papers: Paper 432 showed that the strongest period in a record is the weakest in the forcing—there the strengths of cause and effect disagreed; here their times do. Paper 300 showed that common root and distinct root can be decided—“pressed now” and “pressed once” are distinct roots by that criterion. Paper 425 showed that a delay leaves the amount and takes the certainty—there too delay was the actor. Paper 429 showed that a round trip over the same height does not return the same temperature—here too the load has gone and the shape has not fully returned. What is added is giving the relaxation time at three wavelengths, giving the remaining fraction after ten thousand years as 19.68 per cent, testing that by inverting for the elapsed time, showing that relaxation times go inversely with wavelength, placing a lowered viscosity as the other side of the boundary, and placing the separator at “now or once”.

1. Notation and the Question

Setting: Under a heavy load the mantle beneath flows and the surface sinks. When the load goes, it slowly returns, with a time constant

$$\tau = \frac{4\pi\eta}{\rho g \lambda}$$

where η is the viscosity, ρ the density and λ the wavelength of the load. The remaining depression decays as $\exp(-t/\tau)$. Below, $\eta = 10^{21}$ Pa s and $\rho = 3300 \text{ kg/m}^3$.

Observation 1.1

When the cause goes, the effect is expected to stop. Stop pressing and it stops being pressed—a natural thought.

Observation 1.2

But the land is still rising. More than ten thousand years after the ice went—about a centimetre a year, still moving.

Question: How long does it continue, and how far has it got.

2. The Relaxation Time Is 6152 Years

Computation 2.1: Take the relaxation time at three wavelengths.

Wavelength [km]	Relaxation time [yr]
1000	12305
2000	6152
3000	4102

Observation 2.2

Thousands to tens of thousands of years. Three orders longer than a human life—which is why the intuition “surely it is over by now” fails.

Observation 2.3

The broader the load, the faster it returns. Tripling the wavelength divides the time by exactly **3**—an inverse proportion.

Observation 2.4

This looks backwards. A broader load seems heavier, yet recovers faster—because the flow reaches deeper and more material can move.

Observation 2.5

Divide the viscosity by a thousand and the time divides by **1000**. Proportional—the other side of the boundary, showing that the time comes from the viscosity.

3. After Ten Thousand Years, 19.68 Per Cent Remains

Computation 3.1: At a wavelength of 2000 km ($\tau = 6152$ yr), take the remaining fraction over time.

Elapsed [yr]	Remaining	Recovered
0	1.000000	0.000000
5000	0.443660	0.556340
10000	0.196834	0.803166
20000	0.038744	0.961256

Observation 3.2

After ten thousand years it is not zero.**19.68** per cent remains—a fifth.

Observation 3.3

At the same time **80.32** per cent has recovered.Most of it is over—“still going” and “only just begun” are different.

Computation 3.4: Invert for the elapsed time: $t = -\tau \ln(0.196834)$.

This gives **10000.000000** years, returning the input.

Observation 3.5

Even after twenty thousand years, 3.87 per cent remains.An exponential never quite reaches zero—so this model has no answer to “when does it end”.

Observation 3.6

So “it is still rising” is not surprising.With $\tau = 6152$ years and ten thousand elapsed, only 1.63 time constants have passed—no exponential vanishes in that.

4. The Separator

The separator: does something press now, or did something press once.

Observation 4.1

Land pressed now stops when the load is removed. The response is simultaneous—cause and effect share a time.

Observation 4.2

Land pressed once keeps moving with no load at all. The response lags—the cause is in the past and the effect is now.

Observation 4.3

These are distinct roots by the criterion of Paper 300. Both are called “the ground is moving”—one a present force, one a past one.

Observation 4.4

And they can be told apart. Measure the present load and see whether it matches the motion—if it does not, one goes looking in the past.

Observation 4.5

The length of the memory is set by the material. The relaxation time is proportional to the viscosity—so the stiffer it is, the longer it remembers. What flows least keeps the past longest.

Observation 4.6

To be honest—a single time constant is used here. The real response superposes several, from viscosities that vary with depth—what does not move is that the time constant is of the order of thousands of years.

Observation 4.7

One last thing—“the cause is gone and it continues” is not mysterious. Any system with a time constant does this—it looks mysterious only because the time constant is being measured against a human life.

5. Roll Call and Closing

1. **6152 yr at 2000 km** (Computation 2.1): **thousands of years.**
2. **12305 yr at 1000 km** (Computation 2.1): **narrower is slower.**
3. **Tripling the wavelength gives 1/3** (Observation 2.3): **inverse.**
4. **A thousandth of the viscosity gives 1/1000** (Observation 2.5): **the other side.**
5. **19.68 % remains after ten thousand years** (Computation 3.1): **the core.**
6. **80.32 % has recovered** (Observation 3.3): **most of it is over.**
7. **44.37 % after five thousand** (Computation 3.1): **just under half.**
8. **3.87 % even after twenty thousand** (Observation 3.5): **never quite zero.**
9. **Inversion returns 10000.000000 yr** (Computation 3.4): **a self-test.**
10. **The separator is now or once** (Observation 4.3): **distinct roots by Paper 300.**

Closing: When the cause goes, the effect is expected to stop—stop pressing and it stops being pressed—yet land in Scandinavia and Canada still rises about a centimetre a year, more than ten thousand years after the ice went. How long it continues is fixed by numbers—the relaxation time is $4\pi\eta/(\rho g\lambda)$, giving **6152** years at 2000 km, **12305** at 1000 and **4102** at 3000. Thousands to tens of thousands of years, three orders longer than a human life, which is why the intuition “surely it is over by now” fails. Tripling the wavelength divides the time by exactly **3**: a broader load seems heavier yet recovers faster, because the flow reaches deeper and more material can move. Dividing the viscosity by a thousand divides the time by **1000**, showing where the time comes from. And how far it has got also comes out in numbers—ten thousand years after the ice went, **19.68** per cent of the depression remains, a fifth. At the same time **80.32** per cent has recovered, so “still going” and “only just begun” are different. Inverting the remaining fraction for the elapsed time returns **10000.000000** years. Even after twenty thousand years **3.87** per cent remains, since an exponential never quite reaches zero, so this model has no answer to “when does it end”. With $\tau = 6152$ years and ten thousand elapsed, only **1.63** time constants have passed, and no exponential vanishes in that. One thing separates them—does something press now, or did something press once. Land pressed now stops when the load is removed, cause and effect sharing a time; land pressed once keeps moving with no load, the cause in the past and the effect now. They are distinct roots by the criterion of Paper 300: both are called “the ground is moving”, but one is a present force and one a past one. And they can be told apart—measure the present load and

see whether it matches the motion; if it does not, one goes looking in the past. The length of the memory is set by the material, the relaxation time being proportional to the viscosity, so what flows least keeps the past longest. To be honest—a single time constant is used here, while the real response superposes several from viscosities that vary with depth. What does not move is that the time constant is of the order of thousands of years. One last thing—“the cause is gone and it continues” is not mysterious. Any system with a time constant does this; it looks mysterious only because the time constant is being measured against a human life.

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