the observed time and length scales (~100 ns judging from the micrometer-scale sharpness of the reaction front in Fig. 2A and the 13-m/s propagation speed). These time and length scales are not consistent with an alternative hypothesis that the structures arise from purely solid-state diffusive processes, which are orders of magnitude too slow, even at 1700 K (26).

The dark intensity between the cells fades away in the last micrograph of the series in Fig. 2, at a point in time where the reaction is long since complete. The solid solubility range of the NiAl B2 phase increases as the temperature drops (22), so that at room temperature nearly all of the excess Ni could be reabsorbed into a stable homogene-...
Fig. 1. Sketch describing how Titan’s plasma interaction depends on solar wind pressure. Under nominal solar wind conditions, Titan interacts with Saturn’s rotating magnetosphere (A). When solar wind pressure is high, Titan exits into Saturn’s magnetosheath (B). Both panels indicate Titan’s position during T32.

Fig. 2. (Top) Cassini magnetic field data on 13 June 2007 in spherical KSMAG coordinates. The encounters with the oscillating kronian magnetopause and bow shock are indicated with the letters A to C and D to F, respectively. $|B|$ is the magnetic field strength. Cassini’s kronocentric distance is indicated beneath the plots. (Bottom) Magnetic field data in spherical TIIS coordinates (from MAG), plasma density ($N_e$) (from RPWS/LP), and electron count rate per energy channel (from CAPS/ELS) during the T32 flyby. Magnetopause crossing C, CA, and the entry (I) and exit (II) of the fossil field region are indicated. Cassini’s altitude above Titan is indicated beneath the plots.
During every in situ observation made from Voyager 1 (3) through Cassini close flyby 31 (T31), Titan was inside the kronian magnetosphere. However, during T32 on 13 June (day 164) 2007, Cassini encountered Titan while it was in the shocked solar wind. Observations of the plasma environment showed layers of remnant kronian magnetic fields to which Titan had been exposed a few minutes before, revealing how this field interacts with the IMF.

T32 took place at 13.6 hours SLT, close to the Saturn-Sun line, when the spacecraft was outbound from the kronian system. In the Titan-centered frame, Cassini’s trajectory was almost parallel to the Saturn-Sun direction and north of the moon’s orbital plane. Closest approach (CA) occurred at 17:46:32 universal time (UT) (9) at an altitude of 975 km over the north pole. As a result, Cassini first explored the near-Saturn side of Titan’s induced magnetosphere, then flew through the collisional ionosphere and emerged on the side facing away from the planet.

The T32 encounter occurred after a series of compressions and expansions of Saturn’s magnetopause (at speeds much higher than Cassini’s) in response to strong variations in $P_{SW}$. These oscillations are noticeable in the Cassini magnetometer (MAG) (10) data in the spherical KSMAG coordinate system (11) aligned with Saturn’s magnetic dipole (Fig. 2, top panel). Early on day 164, Cassini was immersed in a typical north/south kronian magnetic field. Then the magnetosphere contracted because of an increase in $P_{SW}$. The receding magnetopause passed Cassini around 04:47 (point A) at a distance of ~15.4 $R_S$ from Saturn. A model of the magnetopause based on pressure balance (12, 13) suggests that $P_{SW}$ was ~0.08 nPa (more than five times the average value). From that moment, Titan was also outside the magnetosphere. Furthermore, if the same dependence on $P_{SW}$ is applied to the bow shock (14), Titan was in the supersonic solar wind at the time of A. After A, Cassini spent almost 10 hours outside Saturn’s magnetosphere. Meanwhile, the magnetopause stopped contracting and expanded once again, reaching Cassini around 14:32 (point B). Cassini was then within the magnetosphere for ~3 hours until it encountered, one last time, a retreating magnetopause around 17:25 (point C), more than 20 min before CA. The magnetic field disturbance generated by Titan was observed by Cassini ~10 min after C. After ~11:00, the IMF was mainly northward, leading to strong magnetic shear at crossings B and C.

The combined capabilities of Cassini MAG, the Radio and Plasma Wave Science instrument (RPWS) (15), and the Cassini Plasma Spectrometer/ Electron Spectrometer (CAPS/ELS) (16) provide a detailed description of the plasma near Titan (Fig. 2, bottom panel). Magnetic field data are shown in the spherical Titan interaction (TIISS) coordinate system defined from the nominal kronian corotation flow (4, 17). In Cassini’s frame of reference, the magnetopause crossing C displayed a thick boundary layer, where the magnetospheric and the magnetosheath plasmas coexisted, where the magnetic field rotated northward by 156°. These signatures are typical of local magnetopause reconnection events previously observed at Saturn (18). Also within C, ELS and the RPWS Langmuir probe (LP) detected (from 17:30) a less energetic (10-eV) electron population that probably originated from Titan. After C (between 17:32 and 17:38, and after 17:53), the magnetic field was predominantly northward, confirming that Titan was in the IMF. The mixed magnetosphere/magnetosheath plasma signature continued until 17:38.

Around 17:41 and 17:53 (altitudes of 1400 and 1740 km, respectively), the sudden drop in 100- to 1000-eV electron count rates indicates that the external flow was strongly decelerated and deflected near Titan, as its cold plasma began to dominate. Simultaneously, the plasma density increased above 100 cm$^{-3}$ and the frequency of collisions became comparable to the ion gyrofrequency. As a result, only electrons remained magnetized and deposited the magnetic field in the induced magnetosphere via convective pileup. These electrons had lost most of their momentum, making the magnetic flux tube convection time extremely long as compared to that at higher altitudes.

From 17:43:30 to 17:49:00 (below an altitude of 1100 km), extremely weak fields indicate that Cassini entered Titan’s collisional ionosphere, where magnetic diffusion dominated over convect-

---

**Fig. 3.** Magnetic field measurements along the trajectories of flybys T30 (blue) and T32 (red) in TIISS coordinates. The draped magnetic fields of Titan’s induced magnetosphere are highlighted in bright colors. Light-colored blue and red arrows indicate the unperturbed ambient field.

**Fig. 4.** Simplified schematics showing, from the same initial scenario and in three stages, possible reconfigurations of the magnetic field near Titan during T32. (Top) Saturn’s magnetopause opens as a result of reconnection between the kronian fossil fields and the IMF (1), and reconnected field lines are carried downstream (2 and 3). (Bottom) The absence of reconnection (i) results in a closed magnetopause that sweeps across Titan’s induced magnetosphere (ii and iii). The shocked solar wind travels from left to right. The formation of the fossil fields and possible tail reconnection are not shown because of the geometrical complexity of the process.
Shear at locations I and II (111° and 162°, respectively) and the magnetic field variance suggest that reconnection could have occurred during T32. In this scenario (Fig. 4, top panels), Titan could have opened Saturn’s magnetopause, and the field reconfiguration could have been similar to that proposed for disconnection events at comets (21). Initial real-time modeling supports this interpretation.

However, previous simulations (20) indicate that at these altitudes, the plasma density was too low for electrons to be demagnetized. In such a case (Fig. 4, bottom panels), reconnection would not have occurred, and the fossilized fields could have been either diffused into the collisional ionosphere or transported downstream by ambipolar electric fields (22) without affecting the magnetic structure of Saturn’s magnetopause.

The bow-shock crossings D, E, and F at kpc distances of 20.8, 21.0, and 21.4 respectively, the magnetic field latitude and azimuth, respectively, the magnetic field direction measured from the interaction region. Essentially this function represents the seismic response of the Earth to ambient seismic noise computed between a pair of receivers converging toward the response of Earth. Ambient seismic noise computed between a pair of receivers converging toward the response of Earth.

References and Notes
7. SLL is measured from the noon meridian in the direction of Saturn’s rotation.
8. P_{SW} is p^0, where p and v are the solar wind density and speed, respectively.
9. All times are expressed in UT.
11. In the Saturn-centered spherical solar magnetic coordinate system (KSMAG), the polar axis coincides with planet’s magnetic axis and \Phi_{KSMAG} and \Theta_{KSMAG} are, respectively, the magnetic field latitude and azimuth (\Phi_{KSMAG} = 0° corresponds to the magnetic noon meridian).
12. \Delta t_{p} = P_{SW}^{−1/3}, where \Delta t_{p} is the magnetopause’s standoff distance.
17. In the Titan-centered spherical ionospheric interaction coordinate system (TIS), the equatorial plane contains the direction to Saturn (\Theta_{TIS} and that of the nominal corotation flow (\Phi_{TIS}), \lambda_{KSM} and \mu_{KSM} are, respectively, the magnetic latitude and azimuth (measured from the interaction region).