30. Gemma and Roxanne agreed they were glad they didn't have to spend nearly a year just getting to Mars!

Roxanne also sent Gemma an image that represented their actual flight plan (Figure 12 below). Roxanne noted that they were taking a relatively slow trip, with the Epstein Drive providing just 1g of constant acceleration and deceleration which would get them to Mars in under 5 days. Gemma knew the answer to her next question but asked it anyway.

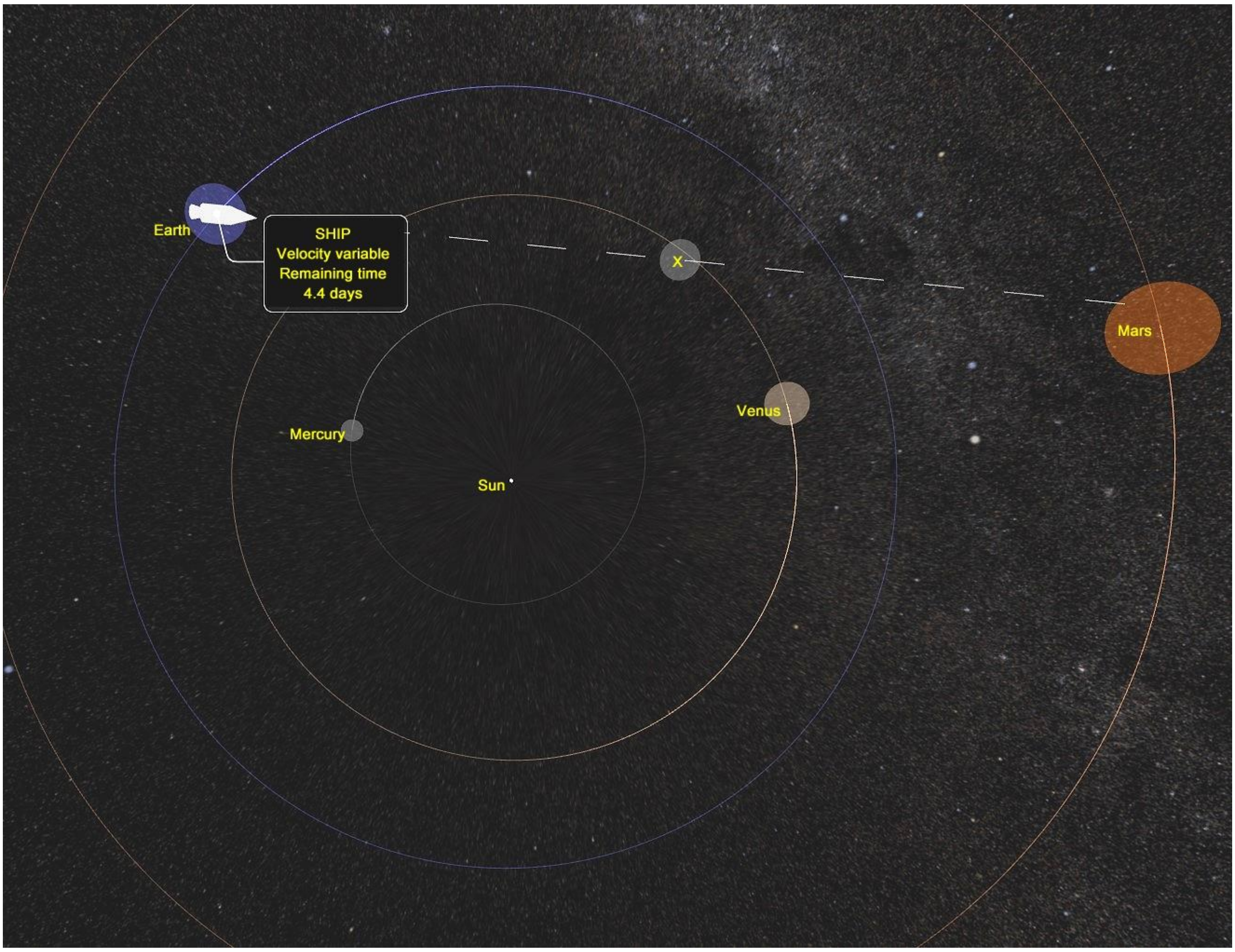

Figure 12: Flight path for the modern way to travel the solar system, taking 4.4 days to arrive at Mars, using 1 g acceleration and deceleration provided by the Epstein Drive.

Coloured dots indicate location of planets on orbital paths, not the size of the planets.

Image courtesy of Planetary Transfer Calculator.

Q: What did Roxanne say in answer to the question: What does the location on the flight path marked X (Figure 12 above) indicate? (1 mark)

a. At this location the ship must point its main thruster at Mars.
b. At this location the ship must point its main thruster at Earth.
c. At this location the ship must double its acceleration from zero g to 2 g in order to achieve an average of 1g.
d. At this location the ship must take evasive action to avoid Venus.
e. At this location the ship must change direction to ensure a rendezvous with Mars.
f. At this location the ship must dock at Venus to deliver the mail.

31. Gemma could not resist bugging her sister one more time! Gemma is planning a mission to Ganymede so has been reading a lot about Jovian exploration recently and observing the Galilean Moons, Io, Ganymede, Calisto and Europa, with her telescope just for fun. The moon Io has an orbital period of a bit less than 2 Earth days and when observed from Earth or Mars it is eclipsed by Jupiter once every orbit. Gemma sent a picture of the relative positions of the inner rocky planets and Jupiter for the time of Roxanne's trip (Figure 13 below).

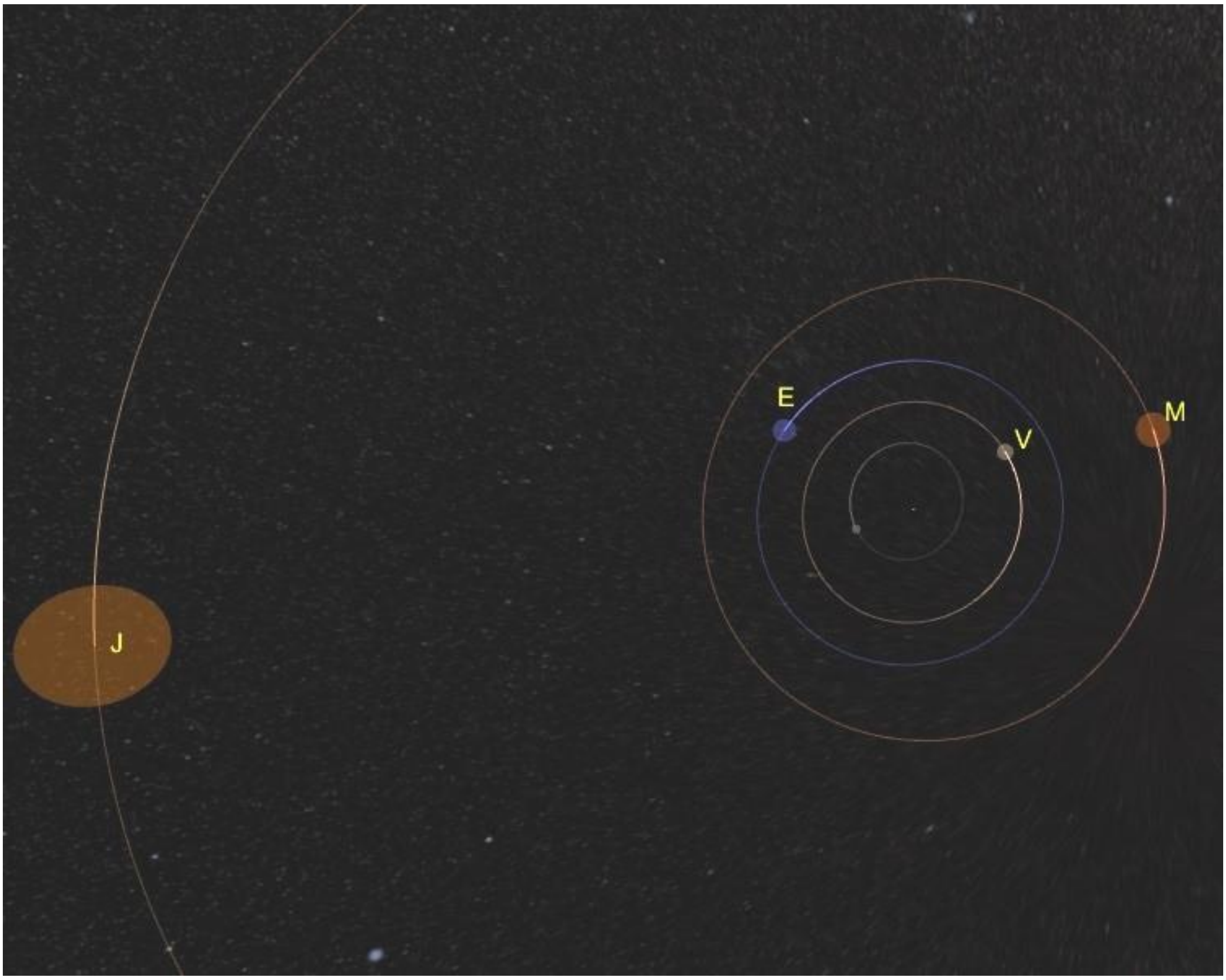

Figure 13: Relative positions of Venus (V), Earth (E), Mars (M) and Jupiter (J) at the time of the planned trip to Mars. Coloured dots indicate location of planets on orbital paths, not the size of the planets.
Image courtesy of Planetary Transfer Calculator.

Gemma said …

Hi Roxy, Here's a challenge! Using a telescope on the Moon, measure the orbital period of Io by measuring the time between successive eclipses. When you get to Mars use a telescope to measure the orbital period of Io again. There will be a difference – what type of difference and why?

Q: What did Roxanne reply to solve the question even before she made the observations? (1 mark)

a. Io's orbital period changes all the time because of Jupiter's gravity.
b. Io's orbital period will appear shorter when viewed from Earth. When viewed from Mars the sunlight has had to travel further.
c. Io's orbital period will appear longer when viewed from Earth. When viewed from Mars the sunlight has had to travel further.
d. Io's orbital period will appear shorter when viewed from Mars. When viewed from Earth the sunlight has had to travel further.
e. Io's orbital period will appear shorter when viewed from Earth. When viewed from Mars the sunlight has had to refract around Venus to reach Mars
f. Io's orbital period will measure the same but Io will look smaller from Mars because it will be further away.

32. The team had started to examine the proposed cross-section (Figure 14 below) accompanying the map (Figure 10) when Roxanne returned to the conversation. It was clear from the map and the cross-section A-A’ that the sequence of events at Jezero Crater involved many processes including periods of erosion and deposition. These events are categorised in Table 3 (in no specific chronological order) as:

Table 3

Event #	Event description
1	Impact by a meteorite, brecciating bedrock (cr) and forming Jezero crater and a distinct crater rim
2	Formation of deltaic deposits on a lake floor, mostly horizontal bedding
3	Volcanic eruptions in the region, blanketing the area with volcanic ash and/or windblown debris from the eruption deposits (Nle)
4	Filling of the Jezero crater with water
5	Crater overflow, resulting in erosion forming an outflow canyon
6	Jezero crater completely empties of water
7	Volcanic eruptions in the region, blanketing the area with volcanic ash and/or windblown debris from the eruption deposits that are ultimately deposited in water (Nue)
8	Volcanic eruptions in the region, blanketing the area with volcanic ash and/or windblown debris from the eruption deposits deposited in water prior to the formation of a delta (Njf)
9	Formation of deltaic fan deposits, steeply dipping delta fan bedding evident in outcrop cliffs
10	Erosional period
11	Mass wasting forming unit “su” after crater wall breached by water
12	Deposition of wind-blown sediments forming unit “Aeb”
13	Formation of Martian crustal rocks
14	Chemical and physical weathering plus wind erosion

Q: What sequence of events (from oldest to youngest) did the team think most likely based on the map evidence and interpretive cross-section (Figure 14)? (2 marks)

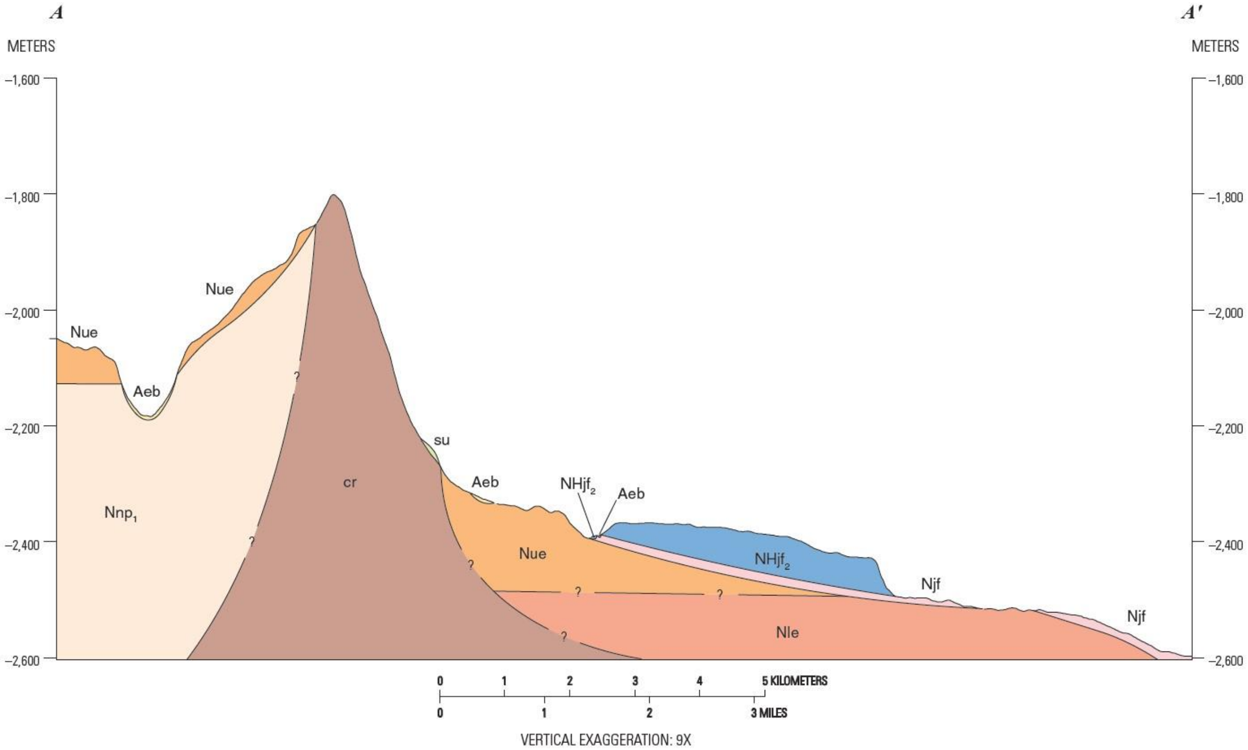

Figure 14: Cross-section along traverse A-A' show on the map (Figure 10). Modified from Sun & Stack 2020 (USGS publication).

a. 13, 1, 6, 10, 7, 10,4, 8, 2, 9, 5, 10, 11, 3, 14, 12, 14
b. 13, 1, 3, 10, 7, 10, 2, 8, 4, 9, 5, 10, 11, 6, 14, 12, 14
c. 13, 4, 3, 10, 7, 10, 1, 8, 2, 14, 5, 10, 11, 6, 9, 12, 14
d. 13, 1, 3, 10, 7, 10, 4, 2, 8, 9, 5, 10, 11, 12, 14, 6, 14
e. 13, 1, 3, 5, 7, 10, 4, 2, 9, 8, 15, 10, 14, 6, 11, 12, 14
f. 13, 1, 3, 10, 7, 10, 4, 8, 2, 9, 5, 10, 11, 6, 14, 12, 14

33. One of the features that caught Philip's eye was the river channel leading into Jezero Crater, with it clearly leading to the deltaic sediments identified as NHjf1 and NHjf2 (Figure 10 and Figures 15 below). He noted there didn't seem to be much need for his metamorphic rock expertise but physical geography fascinates him too. He made the observation that the river channels formation was a major erosional event. It has obviously cut down through the Jezero Crater rim as water and sediments flowed into the crater over time.

Q: What did he speculate was present on this river channel prior to so much rock being removed? (1 mark)

a. A sandy beach at location B (Figure 15).
b. A sandy beach at location B' (Figure 15).
c. A waterfall and/or rapids where the channel first breached the crater wall.
d. A small volcano at location C (Figure 15).
e. A lava tube through the crater wall.
f. A waterfall and/or rapids where the channel cut down through sediments labelled Nue (Figures 14 & 15)

34. Jiki Nakamura agreed there must have been a lot of erosion but noted that as geochronologist they were disappointed there was no way to be sure exactly how old the channel was. However, like Philip, geography was of interest to them.

Q: What was the average gradient of the channel they quickly calculated for the section between B and B' (Figure 15 and Figure 14)? (1 mark)

a. ~1 in 15.
b. ~1 in 23.
c. ~1 in 33.
d. ~1 in 53.
e. ~1 in 73.
f. ~1 in 100.

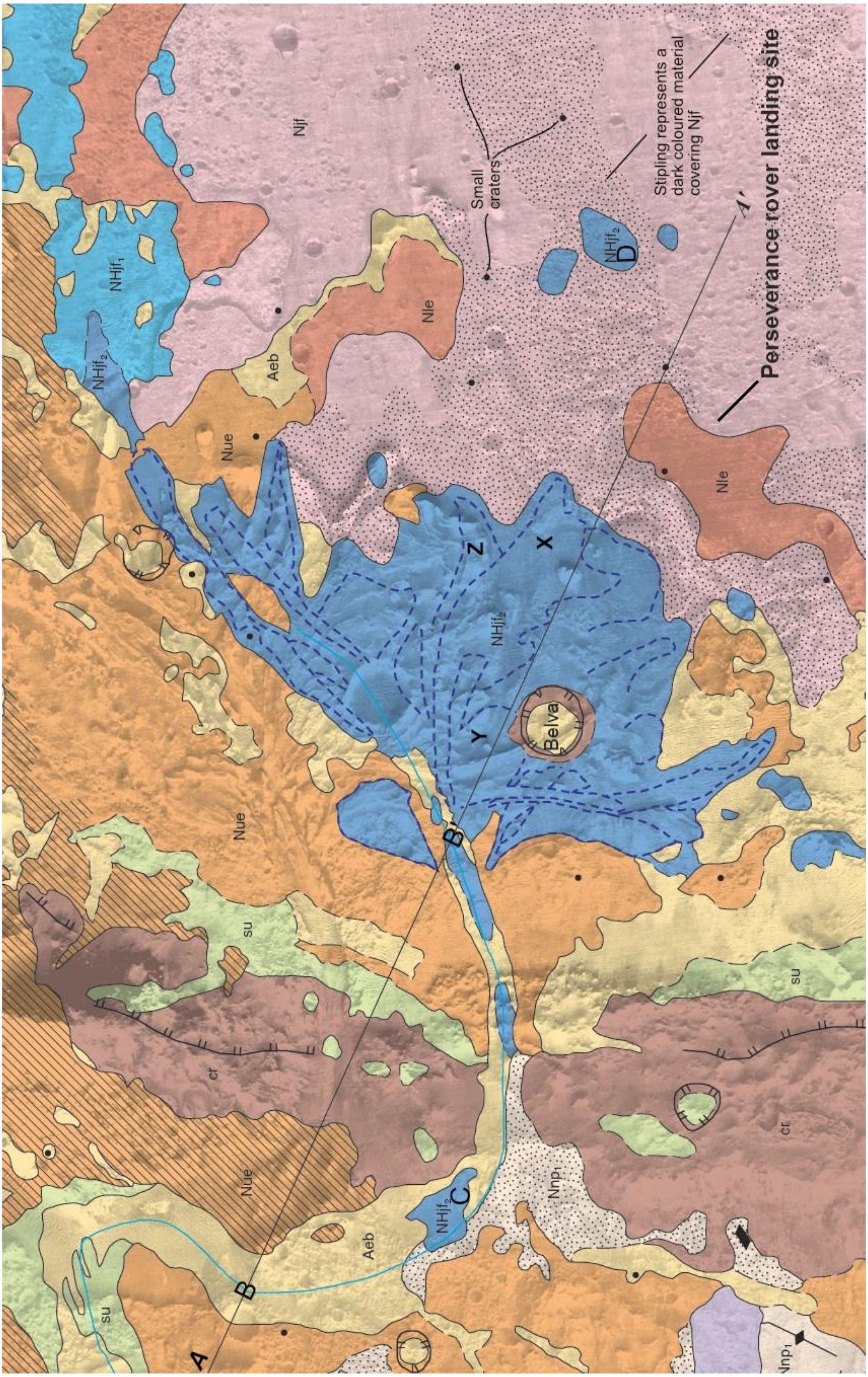

Figure 15: General geology of the Perseverance rover landing site, with additional locations B, B', C and D marked. Modified from Sun & Stack 2020.

35. Jiki asked about the NHjf2 outcrop at location C (Figure 15). They were puzzled about its location within the river channel on the 'outside' of the crater rim.

Q: What did Philip say to explain this, that sedimentologist Sandra agreed with? (1 mark)

a. The deltaic sediments located at site C were deposited there as ejecta from an impact crater.
b. Before the crater rim was breached a lake formed at the wall and a delta formed there.
c. Deltaic sediments at point C are impossible. The outcrop is probably a misidentified mass wasting deposit, more of unit 'su'.
d. The deltaic sediments located at site C were deposited by strong winds blowing them off the top of the delta units labelled X, Y and Z.
e. Deltaic sediments at point C are impossible. The outcrop is probably a misidentified lava flow.
f. At some point the crater was so full of water that it also filled the channel back to point C, allowing deltaic deposits to accumulate there.

36. Jiki also asked about the NHjf2 outcrop at location D (Figure 15, show again below). They were puzzled about its location too.

Q: What did Sandra say to explain this, that Philip nodded in agreement with? (1 mark)

a. The deltaic sediments located at site D were deposited there as ejecta from an impact crater.
b. Deltaic sediments at point D are impossible. The outcrop is probably a misidentified lava flow.
c. Deltaic sediments at point D are impossible. The outcrop is probably a misidentified ash deposit.
d. At some point the deltaic sediments in the region of location X underwent mass wasting and ended up at location D.
e. At some point the delta advanced into the crater lake at least as far as location D but erosion has since removed the sediment between D and the rest of the deltaic sediments.
f. At some point the sediments washing off the delta front at location X were suspended by wave action in the crater lake and settled out at location D.

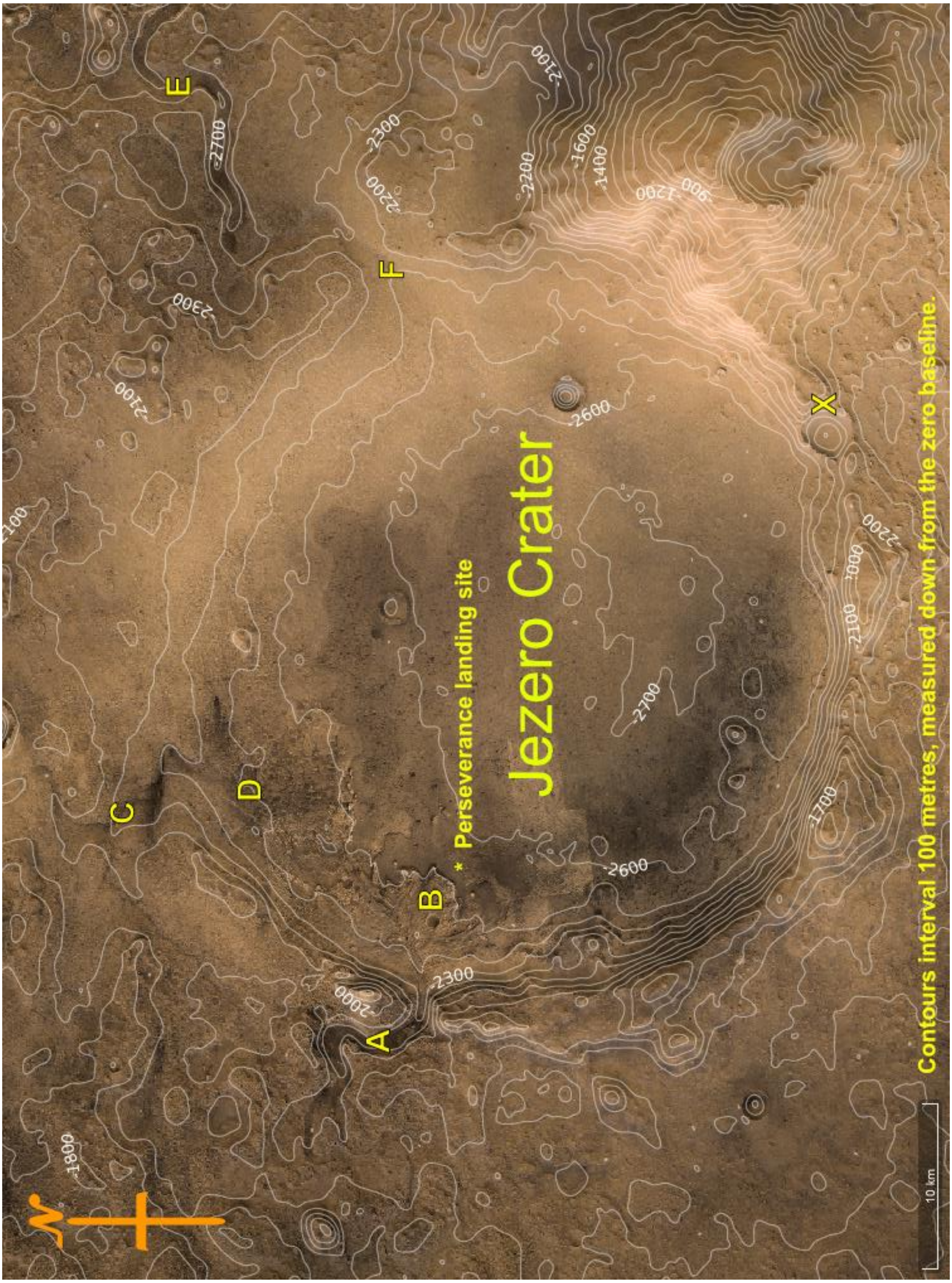

Figure 16: Jezero Crater, showing crater rim and locations A, B, C, D E and F. Map courtesy of NASA and https://maps.planet.fu-berlin.de/jezero/