Supplementary Materials

Forecasting and Structural-Break Characterisation of Water Cut in a Mature Heavy Oil Field: A Multi-Regime Analysis of the Gorisht-Kocul System (2000–2016)

Endri Raço, Brand Karroçi and Enkela Noçka — Processes (MDPI), manuscript processes-4494404

Table S1. Verification of the water-cut identity across the full record: reported water cut against the ratio of free water to total produced fluid, with the implied oil density recovered from the volumetric relation. The maximum absolute deviation is 0.00 percentage points in all 204 months.

Month	Free water (m³)	Total fluid (m³)	Water cut (%)	Recomputed (%)	Deviation (pp)	Implied density (t/m³)
2000-01	5904.2	9824.5	60.10	60.10	0.00	0.877
2000-02	5822.1	9668.6	60.22	60.22	0.00	1.033
2000-03	7415.4	12006.3	61.76	61.76	0.00	0.824
2000-04	7377.2	12457.6	59.22	59.22	0.00	0.797
2000-05	8393.4	14064.8	59.68	59.68	0.00	0.858
2000-06	8914.2	14715.0	60.58	60.58	0.00	0.837
2000-07	9228.3	15168.4	60.84	60.84	0.00	0.845
2000-08	7952.9	13300.8	59.79	59.79	0.00	0.864
2000-09	8149.2	13945.7	58.44	58.44	0.00	0.787
2000-10	8560.2	14399.5	59.45	59.45	0.00	0.764
2000-11	8264.9	13898.7	59.47	59.47	0.00	0.767
2000-12	8412.2	13778.2	61.05	61.05	0.00	0.775
2001-01	8517.1	14250.8	59.77	59.77	0.00	0.735
2001-02	8716.9	14276.2	61.06	61.06	0.00	0.700
2001-03	9568.6	15736.5	60.81	60.81	0.00	0.759
2001-04	9019.5	14772.5	61.06	61.06	0.00	0.787
2001-05	9709.6	15955.0	60.86	60.86	0.00	0.764
2001-06	9608.6	15734.0	61.07	61.07	0.00	0.754
2001-07	10211.6	15768.9	64.76	64.76	0.00	0.870
2001-08	9664.4	15803.8	61.15	61.15	0.00	0.788
2001-09	8349.6	13968.3	59.78	59.78	0.00	0.774
2001-10	8999.8	14780.5	60.89	60.89	0.00	0.767
2001-11	8440.7	13785.9	61.23	61.23	0.00	0.775
2001-12	8653.1	14080.8	61.45	61.45	0.00	0.714
2002-01	8458.9	13493.9	62.69	62.69	0.00	0.714
2002-02	8955.9	14062.0	63.69	63.69	0.00	0.784
2002-03	9730.5	15333.7	63.46	63.46	0.00	0.819
2002-04	9841.8	15565.7	63.23	63.23	0.00	0.791
2002-05	10791.3	16990.5	63.51	63.51	0.00	0.780
2002-06	10514.7	16638.7	63.19	63.19	0.00	0.769
2002-07	10608.6	16972.1	62.51	62.51	0.00	0.760
2002-08	10369.2	16270.2	63.73	63.73	0.00	0.793
2002-09	9947.3	15732.9	63.23	63.23	0.00	0.767
2002-10	10476.3	16127.5	64.96	64.96	0.00	0.834
2002-11	10240.9	15803.8	64.80	64.80	0.00	0.809
2002-12	10055.3	16129.9	62.34	62.34	0.00	0.746
2003-01	10106.5	15815.8	63.90	63.90	0.00	0.771
2003-02	8922.6	14076.7	63.39	63.39	0.00	0.793

Month	Free water (m³)	Total fluid (m³)	Water cut (%)	Recomputed (%)	Deviation (pp)	Implied density (t/m³)
2003-03	10224.0	16173.5	63.21	63.21	0.00	0.792
2003-04	10350.5	16082.1	64.36	64.36	0.00	0.767
2003-05	10824.2	16555.3	65.38	65.38	0.00	0.801
2003-06	10384.4	16123.0	64.41	64.41	0.00	0.768
2003-07	11766.2	17764.2	66.24	66.24	0.00	0.773
2003-08	11168.5	16980.0	65.77	65.77	0.00	0.789
2003-09	10720.2	16708.9	64.16	64.16	0.00	0.739
2003-10	10929.9	16081.4	67.97	67.97	0.00	0.873
2003-11	10554.7	16444.2	64.18	64.18	0.00	0.734
2003-12	10776.1	16870.2	63.88	63.88	0.00	0.725
2004-01	10637.5	16631.9	63.96	63.96	0.00	0.734
2004-02	9816.6	15246.9	64.38	64.38	0.00	0.764
2004-03	10286.6	15860.6	64.86	64.86	0.00	0.801
2004-04	10771.7	16536.8	65.14	65.14	0.00	0.755
2004-05	11277.1	17116.1	65.89	65.89	0.00	0.780
2004-06	11117.1	16372.4	67.90	67.90	0.00	0.849
2004-07	11610.1	17446.1	66.55	66.55	0.00	0.770
2004-08	12060.8	17712.4	68.09	68.09	0.00	0.795
2004-09	11255.5	16410.0	68.59	68.59	0.00	0.844
2004-10	11716.9	17105.5	68.50	68.50	0.00	0.832
2004-11	11418.9	17091.9	66.81	66.81	0.00	0.791
2004-12	11826.2	17724.7	66.72	66.72	0.00	0.785
2005-01	11804.7	17608.5	67.04	67.04	0.00	0.753
2005-02	10621.9	15813.5	67.17	67.17	0.00	0.764
2005-03	11810.4	17381.5	67.95	67.95	0.00	0.796
2005-04	11978.8	17852.5	67.10	67.10	0.00	0.741
2005-05	12405.3	18096.6	68.55	68.55	0.00	0.795
2005-06	11809.0	17370.4	67.98	67.98	0.00	0.793
2005-07	12547.0	18488.2	67.86	67.86	0.00	0.767
2005-08	12610.2	18464.5	68.29	68.29	0.00	0.778
2005-09	12084.9	17621.7	68.58	68.58	0.00	0.796
2005-10	12480.8	17637.3	70.76	70.76	0.00	0.878
2005-11	11913.5	17388.8	68.51	68.51	0.00	0.800
2005-12	12086.6	18032.3	67.03	67.03	0.00	0.764
2006-01	12424.9	18227.0	68.17	68.17	0.00	0.780
2006-02	11417.2	16565.4	68.92	68.92	0.00	0.789
2006-03	15454.0	18094.9	85.41	85.41	0.00	1.690
2006-04	12030.8	17399.8	69.14	69.14	0.00	0.816
2006-05	12452.6	17907.0	69.54	69.54	0.00	0.830
2006-06	12152.2	17717.0	68.59	68.59	0.00	0.792
2006-07	12614.2	18388.1	68.60	68.60	0.00	0.789
2006-08	12941.3	18714.8	69.15	69.15	0.00	0.779
2006-09	12753.3	18394.0	69.33	69.33	0.00	0.654
2006-10	14206.2	19319.4	73.53	73.53	0.00	0.842
2006-11	12961.5	18313.0	70.78	70.78	0.00	0.756
2006-12	13264.9	18316.7	72.42	72.42	0.00	0.804
2007-01	13297.6	18266.9	72.80	72.80	0.00	0.827

Month	Free water (m³)	Total fluid (m³)	Water cut (%)	Recomputed (%)	Deviation (pp)	Implied density (t/m³)
2007-02	11854.0	16317.9	72.64	72.64	0.00	0.826
2007-03	13195.1	18276.3	72.20	72.20	0.00	0.803
2007-04	12898.8	17795.0	72.49	72.49	0.00	0.814
2007-05	12927.2	18090.0	71.46	71.46	0.00	0.803
2007-06	12516.5	17283.0	72.42	72.42	0.00	0.841
2007-07	13013.4	18115.3	71.84	71.84	0.00	0.818
2007-08	13121.0	18357.5	71.47	71.47	0.00	0.796
2007-09	12313.4	17216.0	71.52	71.52	0.00	0.814
2007-10	12791.5	17798.9	71.87	71.87	0.00	0.810
2007-11	11715.5	16113.9	72.70	72.70	0.00	0.812
2007-12	12342.1	16698.8	73.91	73.91	0.00	0.828
2008-01	12488.9	16823.9	74.23	74.23	0.00	0.822
2008-02	11646.5	15709.2	74.14	74.14	0.00	0.819
2008-03	12481.8	17422.3	71.64	71.64	0.00	0.728
2008-04	11990.2	17264.9	69.45	69.45	0.00	0.657
2008-05	12233.9	16630.9	73.56	73.56	0.00	0.815
2008-06	11465.1	15576.3	73.61	73.61	0.00	0.826
2008-07	11297.0	15429.2	73.22	73.22	0.00	0.808
2008-08	11162.7	15354.9	72.70	72.70	0.00	0.804
2008-09	10737.2	14757.0	72.76	72.76	0.00	0.806
2008-10	10620.1	14637.4	72.55	72.55	0.00	0.825
2008-11	10775.1	14659.0	73.51	73.51	0.00	0.830
2008-12	9897.5	14795.2	66.90	66.90	0.00	0.674
2009-01	10991.2	14862.8	73.95	73.95	0.00	0.856
2009-02	10122.8	13633.6	74.25	74.25	0.00	0.848
2009-03	10891.8	14909.2	73.05	73.05	0.00	0.814
2009-04	10612.3	14657.0	72.40	72.40	0.00	0.783
2009-05	11647.6	15668.7	74.34	74.34	0.00	0.806
2009-06	11360.1	15230.0	74.59	74.59	0.00	0.811
2009-07	11731.8	15723.0	74.62	74.62	0.00	0.762
2009-08	11336.1	15304.0	74.07	74.07	0.00	0.809
2009-09	11119.4	14869.0	74.78	74.78	0.00	0.821
2009-10	11892.4	15981.4	74.41	74.41	0.00	0.777
2009-11	11361.0	15116.5	75.16	75.16	0.00	0.820
2009-12	11449.3	15295.2	74.86	74.86	0.00	0.828
2010-01	11625.7	15589.8	74.57	74.57	0.00	0.788
2010-02	10005.2	13531.4	73.94	73.94	0.00	0.761
2010-03	11186.1	15077.5	74.19	74.19	0.00	0.742
2010-04	11429.7	15308.5	74.66	74.66	0.00	0.766
2010-05	11486.5	15344.4	74.86	74.86	0.00	0.791
2010-06	11077.1	14807.0	74.81	74.81	0.00	0.785
2010-07	11186.3	14865.0	75.25	75.25	0.00	0.803
2010-08	10559.6	14169.3	74.52	74.52	0.00	0.801
2010-09	10112.4	13593.8	74.39	74.39	0.00	0.771
2010-10	10700.7	14251.4	75.09	75.09	0.00	0.781
2010-11	9821.7	13257.6	74.08	74.08	0.00	0.712
2010-12	9734.8	13380.7	72.75	72.75	0.00	0.608

Month	Free water (m³)	Total fluid (m³)	Water cut (%)	Recomputed (%)	Deviation (pp)	Implied density (t/m³)
2011-01	11340.5	15171.5	74.75	74.75	0.00	0.851
2011-02	10946.0	14314.0	76.47	76.47	0.00	0.877
2011-03	11564.0	15157.0	76.29	76.29	0.00	0.924
2011-04	11367.4	14948.8	76.04	76.04	0.00	0.898
2011-05	7111.3	9317.5	76.32	76.32	0.00	0.894
2011-06	12082.2	15862.2	76.17	76.17	0.00	0.913
2011-07	12636.3	16486.6	76.65	76.65	0.00	0.926
2011-08	12549.9	16424.4	76.41	76.41	0.00	0.912
2011-09	12077.5	15740.4	76.73	76.73	0.00	0.934
2011-10	12634.9	16294.6	77.54	77.54	0.00	0.966
2011-11	12151.9	15724.5	77.28	77.28	0.00	0.966
2011-12	12397.5	16024.8	77.36	77.36	0.00	0.966
2012-01	11322.8	14790.9	76.55	76.55	0.00	0.965
2012-02	10744.8	13958.8	76.98	76.98	0.00	0.965
2012-03	11833.8	15237.7	77.66	77.66	0.00	0.965
2012-04	11461.4	14662.2	78.17	78.17	0.00	0.965
2012-05	12644.6	16080.5	78.63	78.63	0.00	0.965
2012-06	12646.0	16126.7	78.42	78.42	0.00	0.965
2012-07	13081.4	16742.0	78.14	78.14	0.00	0.965
2012-08	13229.0	16889.6	78.33	78.33	0.00	0.965
2012-09	13258.9	16936.0	78.29	78.29	0.00	0.965
2012-10	13700.3	17553.5	78.05	78.05	0.00	0.965
2012-11	13952.1	17712.2	78.77	78.77	0.00	0.965
2012-12	13145.1	16870.0	77.92	77.92	0.00	0.965
2013-01	14965.1	18818.5	79.52	79.52	0.00	0.965
2013-02	20928.6	25047.5	83.56	83.56	0.00	0.965
2013-03	22257.0	26624.7	83.60	83.60	0.00	0.965
2013-04	22240.0	26404.5	84.23	84.23	0.00	0.965
2013-05	25353.0	29913.3	84.75	84.75	0.00	0.965
2013-06	26648.0	30688.3	86.83	86.83	0.00	0.965
2013-07	27822.0	31900.8	87.21	87.21	0.00	0.965
2013-08	26903.2	30853.4	87.20	87.20	0.00	0.965
2013-09	25952.6	29619.9	87.62	87.62	0.00	0.965
2013-10	26868.7	30497.6	88.10	88.10	0.00	0.965
2013-11	26593.6	30043.3	88.52	88.52	0.00	0.965
2013-12	28265.8	31959.2	88.44	88.44	0.00	0.965
2014-01	29397.0	33314.9	88.24	88.24	0.00	0.965
2014-02	25917.6	29514.8	87.81	87.81	0.00	0.965
2014-03	31301.9	35364.6	88.51	88.51	0.00	0.965
2014-04	32567.2	36390.2	89.49	89.49	0.00	0.965
2014-05	35007.9	38975.9	89.82	89.82	0.00	0.965
2014-06	39847.3	43764.0	91.05	91.05	0.00	0.965
2014-07	42513.0	46624.8	91.18	91.18	0.00	0.965
2014-08	42058.5	46170.1	91.09	91.09	0.00	0.965
2014-09	40127.7	44075.4	91.04	91.04	0.00	0.965
2014-10	41948.2	46027.6	91.14	91.14	0.00	0.965
2014-11	39995.5	43912.3	91.08	91.08	0.00	0.965

Month	Free water (m³)	Total fluid (m³)	Water cut (%)	Recomputed (%)	Deviation (pp)	Implied density (t/m³)
2014-12	39434.0	43063.7	91.57	91.57	0.00	0.965
2015-01	38217.2	41108.0	92.97	92.97	0.00	0.965
2015-02	25615.5	27443.0	93.34	93.34	0.00	0.965
2015-03	33867.2	37239.3	90.94	90.94	0.00	0.965
2015-04	27230.3	30773.6	88.49	88.49	0.00	0.965
2015-05	31933.3	35594.7	89.71	89.71	0.00	0.965
2015-06	35543.8	39087.5	90.93	90.93	0.00	0.965
2015-07	36160.8	39822.7	90.80	90.80	0.00	0.965
2015-08	32733.6	36138.4	90.58	90.58	0.00	0.965
2015-09	29076.8	32216.2	90.26	90.26	0.00	0.965
2015-10	27848.0	31059.8	89.66	89.66	0.00	0.965
2015-11	24767.0	27515.7	90.01	90.01	0.00	1.037
2015-12	21916.0	24645.6	88.92	88.92	0.00	0.965
2016-01	21031.8	23922.0	87.92	87.92	0.00	0.965
2016-02	21411.5	24265.6	88.24	88.24	0.00	0.965
2016-03	20029.1	23144.3	86.54	86.54	0.00	0.965
2016-04	13277.0	15173.0	87.50	87.50	0.00	0.965
2016-05	19135.8	22251.0	86.00	86.00	0.00	0.965
2016-06	18129.6	21144.2	85.74	85.74	0.00	0.965
2016-07	19394.0	22412.6	86.53	86.53	0.00	0.965
2016-08	18922.6	22037.6	85.87	85.87	0.00	0.965
2016-09	17849.7	20709.0	86.19	86.19	0.00	0.965
2016-10	18291.1	21003.5	87.09	87.09	0.00	1.006
2016-11	3160.7	3720.0	84.97	84.97	0.00	0.966
2016-12	7271.9	8845.0	82.21	82.21	0.00	0.966

Table S2. Complete inventory of data corrections, with values before and after treatment and the physical rationale for each. Seven input corrections, five rederivations, one imputed month and one excluded duplicated column are listed.

Date	Variable	Before	After	Rationale
2001-07	TotalFluid_m3	10636.8	15768.9	Recording error; replaced by mean of Jun/Aug 2001
2003-03	FreeWater_m3	1022.4	10224	Decimal shift (recorded 1022.4); consistent with adjacent months
2005-04	TotalFluid_m3	178525	17852.5	Decimal shift (recorded 178525); adjacent months 17382-18097 m3
2005-11	WellDays_eff	41619	4161.9	Decimal shift (recorded 41619); product Oil_t preserved
2005-11	WellRate_t_d	0.105240395011894	1.05	Decimal shift (recorded 0.105); product Oil_t preserved
2007-04	TotalFluid_m3	1779.5	17795	Decimal shift (recorded 1779.5); water cut otherwise exceeds 100%
2010-12	Gas_Nm3	21.1	21100	Decimal shift (recorded 21.1 Nm3); GOR rederived
2001-07	WaterCut_pct	96.003	64.758	Rederived from corrected free water and total fluid
2003-03	WaterCut_pct	6.321	63.215	Rederived from corrected free water and total fluid
2005-04	WaterCut_pct	6.71	67.099	Rederived from corrected free water and total fluid
2007-04	WaterCut_pct	724.855	72.486	Rederived from corrected free water and total fluid
2010-12	GOR_Nm3_t	0.0095	9.5174	Rederived from corrected gas volume
2002-03	WaterCut_pct / TotalFluid_m3	NA	63.458	Missing in source; water cut interpolated, total fluid recovered from free water
2014-01/12	WellDays_eff, WellRate_t_d	NA	NA	2014 column duplicates 2013 exactly; both set missing and excluded from covariates

Table S3. STL trend- and seasonal-strength indices across the smoothing-parameter grid: seasonal windows 7, 11, 25 and periodic; trend windows 13, 25 and 37; with and without robust iterations. Trend strength ranges from 0.968 to 0.985; seasonal strength from 0.000 to 0.372.

s.window	t.window	Robust	Trend strength	Seasonal strength
7	13	TRUE	0.974	0.048
11	13	TRUE	0.972	0.000
25	13	TRUE	0.973	0.004
periodic	13	TRUE	0.974	0.006
7	25	TRUE	0.970	0.040
11	25	TRUE	0.970	0.006
25	25	TRUE	0.972	0.025
periodic	25	TRUE	0.971	0.021
7	37	TRUE	0.969	0.058
11	37	TRUE	0.968	0.008
25	37	TRUE	0.969	0.017
periodic	37	TRUE	0.969	0.020
7	13	FALSE	0.985	0.372
11	13	FALSE	0.982	0.204
25	13	FALSE	0.980	0.109
periodic	13	FALSE	0.979	0.094
7	25	FALSE	0.983	0.361
11	25	FALSE	0.978	0.182
25	25	FALSE	0.976	0.098
periodic	25	FALSE	0.976	0.085
7	37	FALSE	0.981	0.333
11	37	FALSE	0.976	0.168
25	37	FALSE	0.974	0.092
periodic	37	FALSE	0.973	0.081

Table S4. Block-bootstrap distribution of the two break locations (twelve-month residual blocks, 199 replicates, 99 per cent admitting a two-break partition). Both breaks are sharply located; the first falls eleven months after the reporting transition and is reported as confounded with it.

Specification	Break	Estimate	Boot. 5th pct.	Boot. median	Boot. 95th pct.	Replicates within 12 m of join (%)	Converged (%)
Two breaks (as submitted)	1	2011-12	2011-06	2011-12	2011-12	99.5	99
Two breaks (as submitted)	2	2014-06	2014-04	2014-06	2014-06	0	99

Table S5. Chow test of the equality of the covariate-relationship coefficient vectors estimated separately within the two reporting conventions.

Test	F statistic	df1	df2	p-value	Interpretation
Chow, coefficient equality across vintages	1.776	5	193	0.12	No evidence the relationship differs across vintages

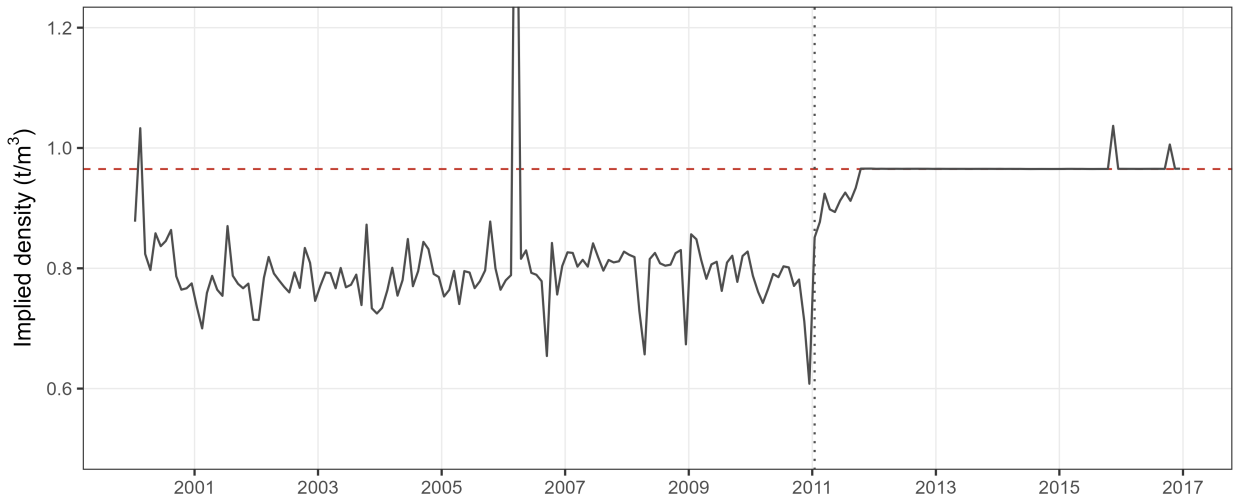

Figure S1. Implied oil density recovered from the volumetric relation across the record. The dashed line marks 0.965 t/m³; the dotted vertical line marks the January 2011 reporting transition. The narrow post-2011 range indicates that total produced fluid in the stream-accounted record is computed rather than independently measured.

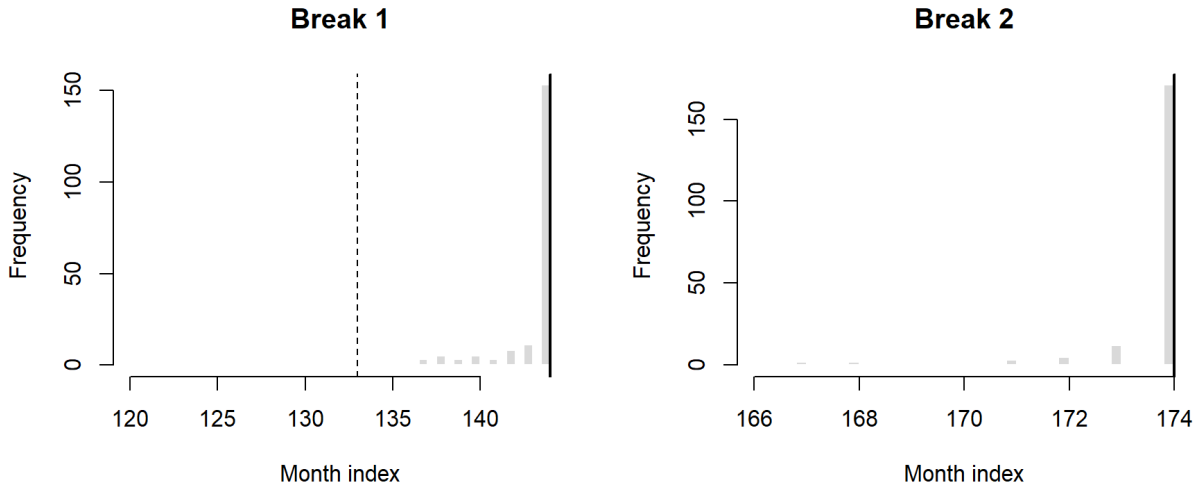

Figure S2. Bootstrap distributions of the two estimated break locations (month index). Solid vertical lines mark the point estimates; the dashed line in the left panel marks the January 2011 reporting transition, eleven months before the first break.