The Canadian Mineralogist
Vol. 56, pp. 159-165 (2018)
DOI: 10.3749/canmin.1700081

JANCHEVITE, $Pb_7V^{5+}(O_{8.5}\square_{0.5})Cl_2$, A NEW MINERAL FROM THE KOMBAT MINE, NAMIBIA

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ABSTRACT

The new mineral janchevite was discovered in Mn-oxide ore from the Kombat mine, Grootfontein district, Otjozondjupa region, Namibia. Associated minerals are baryte, hausmannite, calcite, magnesite, and kombatite. Janchevite forms orange-red thick tabular anhedral to subhedral grains up to $0.4 \times 0.8 \times 0.8$ mm in size. The luster is adamantine. The mineral is brittle, with Mohs' hardness of 2½. Distinct cleavage on {001} is observed. $D_{calc} = 8.16$ g/cm^3. The reflectance values [R_{max}/R_{min}, % (λ, nm)] are: 20.56/20.06 (470), 19.20/18.81 (546), 19.06/18.59 (589), 19.31/18.85 (650). An infrared spectrum indicates the absence of H-bearing groups and indicates V and Mo valences of 5+ and 6+, respectively. The chemical composition is (electron microprobe, wt.%): PbO 91.64, SiO_2 0.45, V_2O_5 1.95, MoO_3 2.41, Cl 4.16, –O=Cl –0.94, total 99.67. The empirical formula based on (Pb + V + Mo + Si) = 8 *apfu* is $Pb_{7.20}V^{5+}_{0.38}Mo^{6+}_{0.29}Si_{0.13}Cl_{2.06}O_{8.25}$. Janchevite is the V-dominant analogue of parkinsonite. The mineral is tetragonal and its unit-cell parameters as determined from single-crystal X-ray diffraction data are: *a* 3.9591(5), *c* 22.6897(3) Å, *V* 355.65(1) Å^3; *Z* = 1. Powder X-ray diffraction data conform to the space group *I*4/*mmm*; the strongest lines of the PXRD pattern [*d*, Å (*I*/*I*$_0$, %) (*hkl*)] are: 3.889 (24) (011), 3.501 (31) (013), 2.979 (86) (015), 2.833 (25) (008), 2.794 (100) (110), 1.992 (26) (118), 1.988 (49) (020), 1.649 (46) (215). Janchevite is named in honor of the prominent Macedonian mineralogist Prof. Dr. Simeon Janchev (b. 1942).

Keywords: janchevite, Kombat mine, Namibia, new mineral, lead vanadate oxychloride.

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Introduction

This paper describes a new mineral species from the abandoned Kombat copper mine located in the Grootfontein district, Otjozondjupa region, northern Namibia. The textural and paragenetic position suggests that the mineral formed as a consequence of regional metamorphism of a primary, Pb-Mn-(As-Ba)-rich, chemically heterogeneous, volcanic hydrothermal assemblage (Innes & Chaplin 1986). This and several related assemblages from the Mn-(Fe) oxide ore unit at Kombat bear a remarkable similarity to some assemblages from the famous Långban mine in Sweden (Nysten *et al*. 1999).

The mineral was named janchevite in honor of the prominent Macedonian mineralogist Prof. Dr. Simeon Janchev (b. 1942), a specialist in the mineralogy and petrology of igneous rocks and metasomatic ore deposits, including endogenous associations of oxygen-bearing minerals of chalcophile elements in the orogenetic zone related to the "mixed series" of the Pelagonian massif in Macedonia. The mineral and its name have been approved by the IMA Commission on New Minerals, Nomenclature, and Classification (IMA no. 2017-079). Janchevite is the 14th new mineral discovered in the Kombat mine.

The holotype specimen of janchevite is deposited in the collections of the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia, with registration number 5105/1.

General Appearance and Physical Properties

Janchevite was discovered in Mn-oxide ore from the Kombat mine. Associated minerals are baryte, hausmannite, calcite, magnesite, and kombatite. Janchevite forms thick tabular anhedral to subhedral grains up to 0.4 × 0.8 × 0.8 mm in size in a polymineralic granular aggregate of associated minerals (Figs. 1, 2).

Janchevite is brittle. The mean hardness determined by the micro-indentation method with a load of 20 g is 85.8 kg/mm^2 (the range over six measurements is 73.4–100.8 kg/mm^2), which corresponds to a Mohs' hardness of 2½. Distinct cleavage on {001} is observed. The density calculated from the empirical formula is 8.160 g/cm^3. Grains of janchevite are translucent, orange-red with orange streak; the luster is adamantine.

Reflectance values (R_{max}/R_{min}) for janchevite (Table 1, Fig. 3) were measured in air using a MSF-21 microspectrophotometer (LOMO JSC, St. Petersburg). SiC (Reflection standard 474251, No. 545, Germany) was used as a standard. Janchevite is weakly anisotropic, with $\Delta R_{589} = 0.47\%$. The color in reflected light is light grey, with deep red internal reflections.

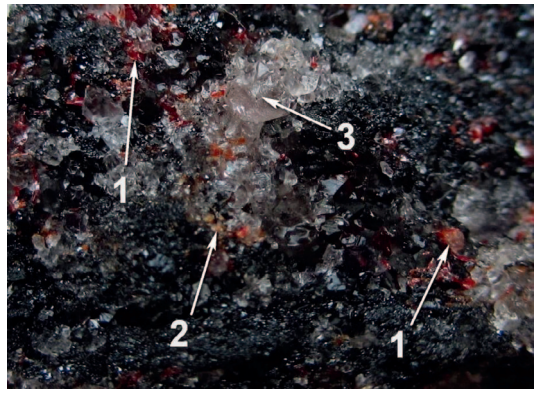

Fig. 1. Grains of janchevite (1), kombatite (2), and baryte (3) in hausmannite aggregate (black). FOV: 4 × 6 mm.

Infrared Spectroscopy

In order to obtain an infrared (IR) absorption spectrum, janchevite powder was mixed with anhydrous KBr, pelletized, and analyzed using an ALPHA FTIR spectrometer (Bruker Optics) at a resolution of 4 cm^{-1}. A total of 16 scans was collected. The IR spectrum of an analogous pellet of pure KBr was used as a reference.

The IR spectrum of janchevite (Fig. 4) contains bands of V^{5+}–O-stretching and Mo^{6+}–O-stretching vibrations (at 736–870 and 595 cm^{-1}, respectively), O–(V,Mo)–O bending vibrations (at 462 and 405 cm^{-1}), and Pb–O-stretching vibrations (at 366 cm^{-1}). No bands corresponding to CO_3^{2-} anions and H-bearing groups are observed in the range 1000–3800 cm^{-1}. The absence

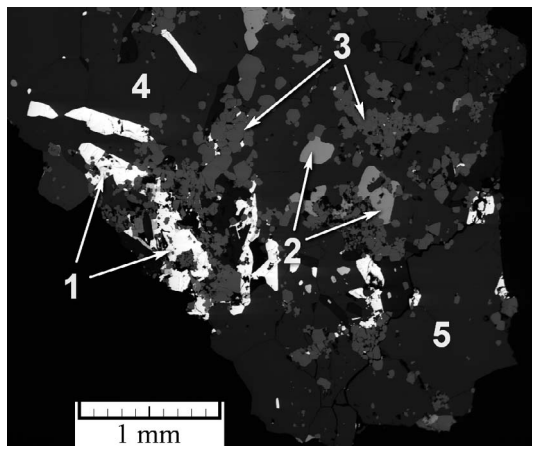

Fig. 2. SEM (BSE) image of janchevite (1) with baryte (2), hausmannite (3), magnesite (4), and calcite (5) in a polished section.

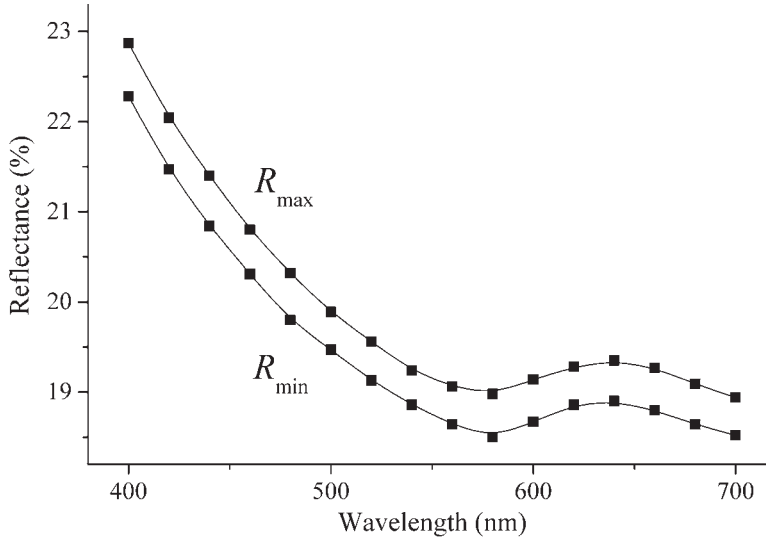

FIG. 3. Reflectance spectra of janchevite.

of IR bands in the range 890–990 cm^{-1} indicates the absence of vanadyl VO^{2+} and molybdenyl MoO^{3+} cations in the structure of janchevite (see Larson & Moore 1963, Kalinnikov *et al.* 1967, Stranford & Condrate 1984, Said *et al.* 1992).

TABLE 1. REFLECTANCE VALUES (R_{max}/R_{min}) FOR JANCHEVITE

λ, nm	R_{max}, %	R_{min}, %
400	22.87	22.28
420	22.04	21.47
440	21.40	20.84
460	20.80	20.31
470	***20.56***	***20.06***
480	20.32	19.80
500	19.89	19.47
520	19.56	19.13
540	19.24	18.86
546	***19.20***	***18.81***
560	19.06	18.64
580	18.98	18.50
589	***19.06***	***18.59***
600	19.14	18.67
620	19.28	18.86
640	19.35	18.90
650	***19.31***	***18.85***
660	19.27	18.80
680	19.09	18.64
700	18.94	18.52

The IR spectrum of janchevite (Fig. 4) differs substantially from the IR spectrum of the chemically related mineral kombatite (Fig. 4).

CHEMICAL DATA

Seven electron-microprobe analyses were obtained using an Oxford INCA Wave 700 electron microprobe (WDS mode, 20 kV, 600 pA, 300 nm beam diameter). Analytical data are given in Table 2. Contents of other elements with atomic numbers >8 are below detection limits.

H_2O and CO_2 were not measured because no bands corresponding to CO_3^{2-} anions or H-bearing groups were observed in the IR spectrum.

The empirical formula based on (Pb + V + Mo + Si) = 8 *apfu* (by analogy with the isostructural mineral parkinsonite; see below) is $Pb_{7.20}V^{5+}_{0.38}Mo^{6+}_{0.29}Si_{0.13}Cl_{2.06}O_{8.25}$. It is to be noted that, in accordance with the IR spectrum (see above), the valence states of V and Mo are 5+ and 6+, respectively. The simplified formula is $Pb_7V^{5+}(O_{8.5}\square_{0.5})Cl_2$. This requires PbO 91.47, V_2O_5 5.32, Cl 4.11, total (–O=Cl 0.93) 100.00 wt.%. The presence of an oxygen vacancy follows from the compositional data and by analogy with the related mineral species asisite (Welch 2004).

X-RAY DIFFRACTION DATA

Powder X-ray diffraction data were collected with a Rigaku R-AXIS Rapid II single-crystal diffractometer equipped with a cylindrical image-plate detector

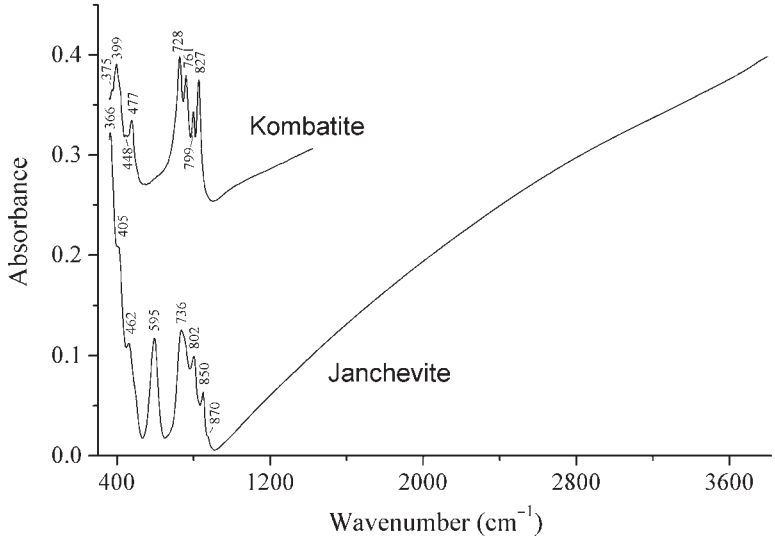

FIG. 4. Powder infrared-absorption spectrum of janchevite. The IR spectrum of kombatite with the empirical formula $Pb_{13.9}Ca_{0.15}O_{9.1}[(VO_4)_{3.9}(AsO_4)_{0.1}]Cl_{3.9}$ from the Kombat mine (drawn using data from Chukanov & Chervonnyi 2016) is given for comparison.

using Debye-Scherrer geometry ($d = 127.4$ mm). Data (for Co$K\alpha$) are given in Table 3. The strongest lines of the PXRD pattern [d, Å (I/I_0, %) (hkl)] are: 3.889 (24) (011), 3.501 (31) (013), 2.979 (86) (015), 2.833 (25) (008), 2.794 (100) (110), 1.992 (26) (118), 1.988 (49) (020), 1.649 (46) (215). The obtained diffraction pattern was indexed in the tetragonal (space group $I4/mmm$) unit cell. Unit-cell parameters refined from the powder data are as follows: a 3.955 (2), c 22.626 (7) Å, V 355.9 (4) Å^3 ($Z = 1$).

Single-crystal X-ray studies were carried out using a Bruker Apex 2 Duo diffractometer with a microfocus X-ray tube operating with Mo$K\alpha$ radiation at 50 kV and 40 mA. In spite of the low quality of even the best of the tested crystals due to their mosaicity, unit-cell parameters corresponding to a parkinsonite-type structure (Table 4) were undoubtedly obtained: a 3.9591(5), c 22.6897(3) Å, V 355.65(1) Å^3.

DISCUSSION

Although the paucity of available material prevented Rietveld refinement, both powder and single-crystal X-ray diffraction data undoubtedly show that janchevite belongs to the same structure type as parkinsonite and asisite. Space group $I4/mmm$ was chosen for janchevite by analogy with parkinsonite and asisite and taking into account systematic absences of reflections in the powder X-ray diffraction pattern.

Janchevite belongs to the family of lead oxychlorides with layered Pb–O blocks. Structural architectures of these minerals consist of Pb–O blocks alternating with tetragonal sheets of Cl^- ions (Siidra *et al.* 2013a). In hereroite $[Pb_{32}O_{20}(O,\square)](AsO_4)_2[(Si,As,V,Mo)O_4]_2Cl_{10}$ (Siidra *et al.* 2013b), kombatite $Pb_{14}O_9(VO_4)_2Cl_4$ (Cooper & Hawthorne 1994), sahlinite $Pb_{14}O_9(AsO_4)_2Cl_4$ (Bonaccorsi & Pasero 2003), asisite $Pb_7Si(O_8\square)Cl_2$ (Welch *et al.* 2004), and

TABLE 2. CHEMICAL COMPOSITION OF JANCHEVITE (IN wt.%)

Constituent	Mean	Range	Standard deviation	Probe standard	Analytical line used
SiO_2	0.45	0.15–0.71	0.18	SiO_2	Si$K\alpha$
V_2O_5	1.95	1.73–2.32	0.19	Vanadinite	V$K\alpha$
MoO_3	2.41	2.19–2.58	0.11	Mo	Mo$L\alpha$
PbO	91.64	90.51–92.30	0.44	PbTe	Pb$M\alpha$
Cl	4.16	3.92–4.34	0.15	Vanadinite	Cl$K\alpha$
–O=Cl	0.94				
Total	99.67				

TABLE 3. POWDER X-RAY DIFFRACTION DATA FOR JANCHEVITE AND RELATED MINERALS AND SYNTHETIC COMPOUND

			Janchevite (this work)			Parkinsonite (Lepore & Welch 2010)		Parkinsonite (Symes *et al.* 1994)		Parkinsonite synthetic analogue (Symes *et al.* 1994)		Asisite (Welch 2004)		Asisite (Rouse *et al.* 1988)	
h	*k*	*l*	d_{calc}, Å*	d_{obs}, Å	I/I_0, %	d_{calc}, Å	I/I_0, %	d_{obs}, Å	I/I_0, %	d_{obs}, Å	I/I_0, %	d_{calc}, Å	I/I_0, %	d_{obs}, Å	I/I_0, %
0	0	2	11.34	11.31	6	11.359	2	11.27	4	11.27	1				
0	0	4	5.672	5.654	10	5.680	10	5.63	85	5.64	20	5.701	9	5.67	10
0	1	1	3.900	**3.889**	**24**	3.918	13	3.931	4	3.925	11	3.838	20	3.83	30
0	0	6	3.782	3.772	4	3.786	1	3.75	15	3.757	4	3.801	4		
0	1	3	3.508	**3.501**	**31**	3.521	31	3.528	8	3.522	25	3.465	15	3.46	40
0	1	5	2.983	**2.979**	**86**	2.993	100	2.988	27	2.986	100	2.961	100	2.957	100
0	0	8	2.836	**2.833**	**25**	2.840	11	2.823	100	2.817	74	2.850	8	2.85	10
1	1	0	2.799	**2.794**	**100**	2.812	45	2.813				2.753	40	2.752	60
1	1	2		2.651	1	2.730	0.05								
1	1	4	2.510	2.506	7	2.520	1					2.498	5	2.495	5
0	1	7	2.508			2.515	5	2.505	6	2.504	8	2.479	1		
0	0	10	2.269	2.268	16	2.272	4	2.251	33	2.256	13	2.280	6	2.276	20
1	1	6	2.250	2.248	8	2.258	3			2.252		2.229	7	2.233	10
0	1	9	2.126	2.119	1	2.131	0.01								
1	1	8	1.992	**1.992**	**26**	1.998	20	1.994	11	1.992	34	1.980	14	1.984	40
0	2	0	1.980	**1.988**	**49**	1.989	20					1.947	18	1.947	30
0	0	12	1.891	1.891	5	1.893	1	1.876	11	1.879	4	1.900	1		
0	2	4	1.869	1.869	2	1.877	2	1.88	2			1.842	1		
0	1	11				1.833	0.01					1.830	1		
1	1	10	1.763	1.763	32										
2	1	3	1.724	1.723	14	1.732	7	1.7367	2	1.733	3	1.697	3	1.7	5
2	1	5	1.649	**1.649**	**46**	1.656	30	1.6598	6	1.6577	19	1.627	28	1.627	60

* Calculated with the unit-cell parameters determined from single-crystal X-ray diffraction data.

parkinsonite $Pb_7MoO_9Cl_2$ (Lepore & Welch 2010) the stacking sequence of the sheets is …Cl|Pb–O|Pb–O|Cl|Pb–O|Pb–O|…, *i.e.*, the (Pb–O):Cl ratio is 2:1. According to the original structure determination of asisite (Welch *et al.* 2004) and charge-balance requirement, this mineral is oxygen-deficient as compared to parkinsonite. Another possible stacking sequence is 1:1 (…Cl|Pb–O|Cl|Pb–O|Cl…) with simple alternation of the Pb–O blocks and sheets of Cl^- ions. This type of structure was observed in vladkrivovichevite $[Pb_{32}O_{18}][Pb_4Mn_2O]Cl_{14}(BO_3)_8{\cdot}2H_2O$ (Siidra *et al.* 2013c), mereheadite $Pb_{47}O_{24}(OH)_{13}Cl_{25}(BO_3)_2(CO_3)$ (Krivovichev *et al.* 2009), symesite $Pb_{10}(SO_4)O_7Cl_4(H_2O)$ (Welch *et al.* 2000), schwartzembergite $Pb_5I^{3+}O_6H_2Cl_3$ (Welch *et al.* 2001), and blixite $Pb_8O_5(OH)_2Cl_4$ (Krivovichev & Burns 2006). Various substitution mechanisms of PbO_n groups in the Pb–O blocks by MO_m polyhedra (M = S, Mo, V, As, I, Si, B, C) are observed in minerals and synthetic compounds (Siidra *et al.* 2013a). The substitution may be either ordered (*e.g.*, in symesite, kombatite, and vladkrivovichevite) or disordered (in parkinsonite, asisite, and schwartzembergite). The disordered substitution mechanism is also observed in janchevite.

Janchevite is a vanadium-dominant structural analogue of parkinsonite $Pb_7MoO_9Cl_2$ (Lepore & Welch 2010). It is also closely structurally related to asisite $Pb_7SiO_8Cl_2$ (Welch 2004, Rouse *et al.* 1988). Superstructure was detected in both minerals (Welch 2004, Lepore & Welch 2010), but the crystal structures of asisite and parkinsonite could only be refined in tetragonal subcells (Table 4). A similar situation was also reported for schwartzembergite $Pb_5I^{3+}O_6H_2Cl_3$ (Welch *et al.* 2001) where the *a* unit-cell parameter is, in fact, the same as that of janchevite, parkinsonite, and asisite, but the *c* parameter is nearly halved.

TABLE 4. COMPARATIVE DATA FOR JANCHEVITE AND RELATED MINERALS

Mineral/compound (source)	Janchevite (this work)	Parkinsonite (Lepore & Welch 2010)/ synthetic analogue (Lepore & Welch 2010)	Asisite (Welch *et al.* 2004; Rouse *et al.* 1988)	Schwartzembergite (Welch *et al.* 2001)	Kombatite (Rouse *et al.* 1986; Cooper & Hawthorne 1994)
Endmember formula	$Pb_7V^{5+}(O_{8.5}\square_{0.5})Cl_2$	$Pb_7MoO_9Cl_2$	$Pb_7Si(O_8\square)Cl_2$	$Pb_5^{I\,3+}O_6H_2Cl_3$	$Pb_{14}O_9(VO_4)_2Cl_4$
Empirical formula	$Pb_{7.20}V_{0.38}Mo_{0.29}Si_{0.13}O_{8.25}Cl_{2.06}$	$Pb_{7.23}Mo_{0.40}V_{0.37}O_{8.90}Cl_{1.82}$/ $Pb_{7.28}Mo_{0.72}O_{8.96}Cl_{1.96}$	$Pb_7Si_{0.55}O_{7.07}Cl_{2.07}$	$Pb_5^{I\,3+}O_6H_2Cl_3$	$Pb_{13.7}V_{2.10}O_{17.1}Cl_{3.9}$
Crystal system	Tetragonal	Tetragonal	Tetragonal	Tetragonal	Monoclinic
Space group	*I*4/*mmm*	*I*4/*mmm*	*I*4/*mmm*	*I*4/*mmm*	*C*2/*c*
Unit cell data					
a, Å	3.9591(5)	3.9570(3)/3.9773(4)	3.8932(6)/3.897(2)	3.977(1)	12.682(2)
b, Å					22.5660(50)
c, Å	22.6897(3)	22.634(5)/22.718(4)	22.803(4)/22.81(2)	12.566(4)	11.279(2)
β, °					118.11(1)
V, Å^3	355.65(1)	354.40(5)/359.38(5)	345.63(10)/346.3(3)	198.8(2)	2847.11
Z	1	1	1	1	4

Janchevite is chemically related to kombatite $Pb_{14}O_9(VO_4)_2Cl_4$ (Cooper & Hawthorne 1994). However, the crystal structure and powder X-ray diffraction pattern of kombatite are quite different from those of janchevite. The latter also differs from kombatite in physical properties, including IR spectrum (Fig. 4) and color.

Kombatite associated with janchevite is Mo-poor and has the empirical formula (based on 7 WDS analyses) $Pb_{13.9}V^{5+}_{1.8}Mo_{0.1}Si_{0.2}Cl_{4.1}O_{17.05}$. For the analytical data see Table 1S in the repository (available from the MAC website, document CM56-2_10.3749/canmin.1700081).

Acknowledgments

This study was supported by the Russian Scientific Foundation, grant no. 14-17-00048 (for part of the investigations into chemical composition and physical properties) and Russian President grant MD-5229.2018.5 (X-ray diffraction studies). Technical support by the X-Ray Diffraction Resource Centre of Saint-Petersburg State University is gratefully acknowledged. The authors are grateful to Dr. Pietro Vignola and Dr. Anthony R. Kampf for their valuable comments.

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Received November 17, 2017. Revised manuscript accepted February 2, 2018.