

5HVHDFK \$UWLF0H

2SHQ \$F

*HQRW\SLQJ RI %DFLOOXV DQWKUDFLV 6WUDL

\$UGL 3HFXOLQXHOH &DP\SHLVHQD 6HUUHFFKDDGR 0DBDQSD %REJHQD %LQHRVLD \$19DORQWLQD 0XKLBKULR
*LDQQJURDQG \$QWRQLR)DVDQHOOD

,QVWLWXWL L 6LJXULVs 8VKTLPRUH GKH 9HWHULQDULVs 5UXJD \$OHNVDQGsU 0RLVLX 7LUDQs \$OEDQL
,VWLWXWR =RRSURILODWLFR 6SHULPHQWDOH RI 3XJOLD DQG %DVLQDFDWD \$QWKUD[5HIHUHQFH &HQW
&RUHVSRQGLQJ DXWKRU 'U \$QWRQLR)DVDQHOOD ,VWLWXWR =RRSURILODWLFR 6SHULPHQWDOH RI
)RJJLD ,WDO\ 7HO D IDVDQHOOD#LJVIJ LW

5HFHLYHG 1QDWHU \$FFHSHWG-GRXDU\ 3XEOJLWKXGDDWH
&RSULJKW 3HFXOL \$ HW DO 7KLV LV DQ RSHQ DFFHVV DUWLFOH GLVWULEXWHG XQGHU WKH WHUPV R
FDVHV LQ ZKLFK WZR GLIIHUHQW JHQRW\SHV ZHUH IRXQG LQ WKH VDPH FDUFDVV WKH DXWKRU V
WKDQVGLRQ RQ GRZRHQWLVHQRV\SHVDFRROGHEHHDQFWRILGLGIBUWQW &XWELGHNLQ WKH VDPH



.HIZRUGSVOEDQLD 0ROHFXODU HSLGHPLOVDASHSDUWHGUDHIF&HSON6113RU VRRPH (DVWHU
0/9\$ %DFLOOXV DQWKUDFLV FRXQWULHV VXFK DV ,WDO\ \$OEDQLD *UH
7XUNH\ LQ SDUWLFXODU DICHVSRSAKOBV

,QWURGXFWRQ FRQWURO SU

\$QWKUD[ZKRVH FD%D5MLOXIVDQVQVQV V DWWHQXDWH
FRQWUJLRXV LQIHFWLRXV GLVHVVH WKDW DIIHFWV VHYHUDO DQLPDUKSKFDIV
KXPDQ RQH LQFOXGHG 'RPHVWLF DQG ZLOG UXPLQDQWV UHSUHVHQWVWKHWHQ
PRVW VXFVHFWLEOH FDWHJRULHV > @ 7KH EDFWHULDO DJHQW KIDVWEPH @
FKDUDFWHULVWLF RI SURGXFLQJ VSRUHV WKDW FDQ VXUYLYH LQ WKH HQWURQPI
IRU VHYHUDO GHFDGHV > @ ,Q VXFVHFWLEOH DQLPDOV DQWKUD[JHQHFDQWKSU
IDWDO RXWFRPH FKDUDFWHULJHG E\ VXGGHQ GHDWK DQG OHNDNDJHWVWQRKDV
FRPLQJ RXW IURP WKH QDWXUDO RSHQLQJV ,Q KXPDQ EHLQJV VXFK DZDNDXNH
GHYHORSV LQ WKUHH ZD\ DQG IRUPV GHSHQGLQJ RQ WKH URXWVHVRUYDWLR
SHQHWUDWLRQ RI WKH EDFWHULXP FXWDQHRXV SXOPRQDU\ DQG GHGD D
JDVWURLQWHVWLQDO > @ 5HFHQWO\ D IRXUWK IDWDO IRUP KDV EHWQLVHISRQW
GUXJ XVHUV DV D UHVXOW RI LQMFWLRQ RI KHURLQ FRQWUPLQDWHGZLNDQVWK
VSRUHV > @ 7KDQNV WR WKH FRQVLGHUDEOH DELOLW\ RI VSRUHV WR PDLQWDL
YLDELOLW\ DQG SDWKRJHQLFLW\ IRU PDQ\ GHFDGHV DQG WKDQNV WR LWV ORZ
FRVW RI SRQDQVLFQRWLGHUHG RQH RI WKH SDWKRJHQV RI
JUHDWHV LQWHUHV DV D EDFWHULRORJLQDO ZHDSRQ LQ D SRVVLEOH ELRWHU
DWWDFN > @ +RZHYHU WKH NQRZOHGJH RI WKH GLVHVVH WKH FDXVDWLYH DJHQ
WKH PRGH RI WUDQVPLVLRQ WKH GHYHORSPHQW RI DQ HIIHFWLYH YDFFLQH DQ
HVSHFLDOO\ WKH FRUHFV PDQDJPHQW RI WKH LQIHFWHG FDUFDVVHV KDYH
FRQWULEXWHG WR WKH QDUO\ GLVDSSHQDQFH RI WKLV GLVHVVH ,Q DJULFXOV
DUHDV RI WKH LQGXVWULDOLJHG FRXQWULHV VSRUDGLF RXWEUHDNV RI DQLPD
DQWKUD[VWLOO WHQG WR RFFXU LQ SODFHV ZKHUH LQIHFWHG DQLPDOV ZHUH
SUHYLRXVO\ EXULHG LQDSSURSULDWHO\ RU ZKHUH WKH\ ZHUH SODFHG LQ ZDVWH
WDQQHULHV 2XWEUHDNV DUH RIWHQ UHSRUWHG DV D UHVXOW RI WKH LQWURGXI
RI FRQWUPLQDWHG IHHG 'HVSLWH WKH VWDQGDUG RI WKH GHYHORSQJ
FRXQWULHV DQWKUD[LV VWLOO D VHULRXV KHDOWK SUREOHP IRU ERWK DQLPD
DQG KXPDQV > @ &XUHQWO\ LQ (XURSHDQ DQWKUD[KDV DOPRVW HQWLUHO\

&LWDWBRICXOL \$ &DPSHVH (6HUUHFFKLD / 0DULQR / %DFLOOXHWEDDOKLQDF &VHOFKOWSLDQJFR
%LRWHUURU %LRGHI

3DJH RI

DQ HSLGHPLRORJLFDQ SLFWXUH WKDWGLORHWHGRVSRIOVHRSRZQGV WRHWHKGLWHDG
VLWXDWLRQ 7KLV SDSHU UHSRUW%DFKPHUHVXGRXURI JSHORWVSHKDOZSCHULRGRWKH
DQWKVDFLDLQV LVRODWHG IURP GHG DQGLDQV DQG IURP VRLO VDP SOHV
FROOHFWHG LQ DUHDV RI \$OEDQLD FRQVLGHUHG DW KLJK ULVN RI DQWKUD[
([WUDFWLRQ RI '1\$

0DWHULDOV DQG 0HWKRGV

6RLO VDP SOHV

6RLO VDP SOHV ZHUH FROOHFWHG LQ 4LEHU DO VLWHV RI GHG DQLPDOV ZLWK
VXVSLFLRQ RI DQWKUD[LQ WKH GLVWULFWV RI 6KNRG-U 9ORU- /XVKQM-
.XUELQ 7HSHOHQ- 'LE-U .XN-V (OEDVDS .RU©- %HUDW DQG *MLURNDVW-U
)LJXUH



)LJXUHDS RI \$OEDQLD LQGLFDWLQJ
H[DPLQH LQ WKLV LQYHVWLJDWLQJ

(DFK VXVSHFW FRORQ\ ZDV WUDQVIHUH
KRXUV RI LQFXEDWLRQ ZDV WDNHQ DGH
VXEMHFWHG WR '1\$ H[WUDFWLRQ XVLQJ W
LEHU DO VLWHV RI GHG DQLPDOV ZLWK
VXVSLFLRQ RI DQWKUD[LQ WKH GLVWULFWV
RI 6KNRG-U 9ORU- /XVKQM-
.XUELQ 7HSHOHQ- 'LE-U .XN-V (OEDVDS
.RU©- %HUDW DQG *MLURNDVW-U
'1\$V ZHUH VXEMHFWHG WR 3RO\PHUDVH
DQWKUD[VSHFLILF SULPHUV IRU WKH VHT
DQG S;2 DQG SULPHUV VSHFLILF IRU WKH

&DQ613 DQDO\VLV

:H XWLQJHG 7DT0DQ 0LQRU *URRYH
GLVFULPLQDWLRQ DVVD\ ZLWK ROLJRV D
> @ IRU HDFK RI &DQ613V (DFK w
7DT0DQ *HQRW\SLQJ 0DVWHU 0L[\$SSOLH
HDFK SUREH DQG Q0 HDFK RI IRUZDUC
DSSUR[LPDWHO\ QJ RI WHPSODWH '1\$)
SDUDPHWHUV ZHUH r& IRU PLQ IROORZ
V DQG r& IRU PLQ (QGSRLQW IOXRVFH
\$% +7 &DQ613V SURLOHV ZHUH FRPS
ZRUOGZLGH VXEOLQHDJHV DQG VXEJURXS

613 GLVFULPLQDWLRQ E\ +50

:H XVHG +LJK 5HVROXWLRQ 0HOWLQJ +5
&DQ613 > @ XVLQJ 3UHFLVLRQ 0HOW \$
EDVHG RQ WKH \$PHV \$QHFWRU JHQRPH
\$PSOLILFDWLRQ ZDV SHUIRUPHG RQ &); &
'%,25\$' XVLQJ WKH 3UHFLVLRQ 0HOW VXSI
PL[WXUH FRQVLVWHG RI w0 RI HDFK
WKHSHULIL%25\$WKH DDPSONHVQDO YROXPH
ZHUH XVHG PLQ DW r& ZHUH IROORZH
DW r& DQG V DW r& 6DPSOHV ZHUH
FRROHG GRZQ WR r& IRU PLQ DQG KHDW
r& V +50 GDWD ZHUH DQDO\JHG E\ 3UHFL

%DFWHULDO VWUDLQV

)URP WKH ,QVWLWXWL L 6LJXULV- 8VKTLORFH GRH \$OGLS DQDO\VLV DQVZMUDQD
HOHYHQ VWUDLQVRIOSVHG IURP VKHHS GLHG LQ VHYHUDO
GLVWULFWV RI WKH \$OEDQLD WHUULWRVH XZHJLQV IURP VHFHOW ODFHOG
&HQWUH IRU \$QWKUD[DW WKH ,VWLWXWL VSHFLILFDORVHOFWGH IRU WKH 5DUL
%DVLQDFDWD \$RJJLD ,WDO\ 7KH GLVWULFWV IURP ZLFLK WKH VWLQDLOV FDFPH
ZHUH 9ORU- /LEUDJG 6KNRG-U /HJK SULPHU SDLUV IRU WKH \$XOWLORFXV 9D
VKLSPHQWV ZHUH PDGH LQ DFFRUGDQFH 0/9\$ XHJLQV LQVWLWXWL \$OO VLFLEHG E\
RI ELRVDIHW\ SULPHU SDLUV ZHUH VHOHFWHG IRU 615 W

,VRQDWRLODQVRIODVFLRLO VDP SOHV

7KH VRLO VDP SOHV ZHUH DQDO\JHG E\ \$PHV \$QHFWRU JHQRPH
5HSHULILFDWLRQV IURP IRU WKH 5DUL
DGGHG PO RI D DTXHRXV VROXWLRQVRIOSVHG IURP VHFHOW ODFHOG
LQ PDJQHWLF VWLUUHU IRU PLQXWHV WKH VXSHQWLRQ ZDV FDFPH
PLQXWHV DW USP DQG WKH VXSHQWLRQ ZDV FDFPH
DW r& \$IWHU LQFXEDWLRQ WKH VXVSLFLRQ ZDV FDFPH
3KRVSKDWH %URWK FRQWDLQLQJ wJPOPHVRIOSVHG IURP VHFHOW ODFHOG

DSSUR[LPDWHO\ QJ RI WHPSODWH '1\$ 7KH WKHUPRF\FOLQJ FRQGLWLRQV
ZHUH WKH VDPH IRU VLQJOHNSOH[DQG DQG PXOWLSOH[DQG DV IROORZV
r & IRU PLQ F\FOHV DW r & IRU V DW r & IRU V DQG DW r
& IRU V DQG ILQDOO\ r & IRU PLQ 7KH FRQGLWLRQV IRU PXOWLSOH[
ZHUH r & IRU PLQ F\FOHV DW r & IRU V DW r & IRU V DQG
DW r & IRU V DQG ILQDOO\ r & IRU PLQ IRU PXOWLSOH[r & IRU
PLQ F\FOHV DW r & IRU V DW r & IRU V DQG DW r & IRU PLQ
DQG ILQDOO\ r & IRU PLQ IRU PXOWLSOH[r & IRU PLQ F\FOHV DW
r & IRU V DW r & IRU V DQG DW r & IRU PLQ DQG ILQDOO\ r &
IRU PLQ 7KH 615 ZDV SHUIRUPHG LQ D PXOWLSOH[3&5 UHDFWLRQ > @ LQ
D ILQDO YROXPH RI wO FRQWDLQLQJ ™ 3&5 UHDFWLRQ EXIIHU 4LDJHQ
8 RI +RW6WDU7DT 3OXV '1\$ SRO\PHUDVH 4LDJHQ G173V P0
HDFK P0 ~~DSSO~~RSULDWH FRQFHQWUDWLRQV RI IRUZDUG DQG
UHYHUVH SULPHUV w0 +0 w0 +0 w0 +0 w0
+0 DQG DSSUR[LPDWHO\ QJ RI WHPSODWH '1\$ 7KH WKHUPRF\FOLQJ
FRQGLWLRQV ZHUH DV IROORZV r & IRU PLQ F\FOHV DW r & IRU V
r & IRU V DQG r & IRU V DQG ILQDOO\ r & IRU PLQ

\$XWRPDWHG JHQRW\SH DQDO\VLV

7KH 0/9\$ 3&5 SURGXFWV ZHUH GLOXWHG DQG VXEMHFWHG WR
FDSLOODU\HOHFWURSKRUHVLV RQ \$%, 3ULVP JHQHWLF DQDO\]HU \$SSOLHG
%LRV\VWHPV ZLWK

:LWK UHJDUG WR WKH VWUDLQV VHQW E\ ,QVWLWXWL L 6LJXULV- 8VKTLPRUH GKI
9HWHULQDULV- RI 7LUDQD DOO WKRVH VHQW IURP WKH GLVWULFW RI 9ORU- ZH
IRXQG WR EHORQJ WR JHQRW\SH \$OEDQLD *7 ZKLOH WKH VWUDLQV IURP WKH
GLVWULFWV RI 6KNRG-U DQG /LEUDJKG EHORQJ WR WKH \$OEDQLD *7 DQG WKH
VWUDLQV IURP WKH GLVWULFWV RI .XUELQ DQG /HJK- ZHUH IRXQG WR EHORQJ WR

)UDJPHQW VLJH ES IRU HDFK ORFXV															
HQRW\SHV	VLJH	YUU	YUU	%YUU	%YUU	&YUU	&&	S;2	S;2	9175	9175	9175	9175	9175	9175	9175	
%D)	REWDLQHG																
5HIHUHQFH	QFH																
VWUDLQ	H[SHFWHG																
\$OEDQL*7	REWDLQHG																
	H[SHFWHG																
\$OEDQL*7	REWDLQHG																
	H[SHFWHG																
\$OEDQL*7	REWDLQHG																
	H[SHFWHG																

7DEOBHVXOWV RI ORFL% / 9DQ DQWDLQW FQ UFXC%DWLQ)* LZD \$ OEDQL JHG E\ 9DQ (GHVLJQDWLRQ QXPEHU \$,7\$ DQG .HLP HW DO > @ ZLWK GHVLJQDWLRQ QXPEHU

,Q VXPPDU\ WKH IHZ FDVHV RI DQWKUD[WKDW RFFXU HDFK \H DU DUH RQO\ WKH UHVXOW RI D QDWXUDO HFRORJLFDQ EDODQFH WKDW WKURXJK WKHVH H[WUDRUGLQDU\ HYHQWV SURPRWHV WKH PDLQWHQDQFH RI D EDFWHULDO VSHFL WKDW RWKHU ZRXOG KDYH EHFRPH H[WLQFW D ORQJ WLP DJR > @

7KHUHIRUH WKH LQWHQVH UHSOLFDWLRQ FDQ SURPRWH WKH GHYHORSPHQW RI PRUH VXE JHQRW\SHV DQG WKH UHVHDFK RQ WKHP FDUULHG RXW WKURXJK WKH DQDO\VLV RI 615V FDQ EH RI JUHDW KHOS LQ WKH PROFXODU HSLGHPLRORJ\ VWXGLHV RI DQWKUD[RXWEUHDNV EHFDXVH LW DOORZV UHVHDFKHUV WR EH DE PDNH D GHWDLOHG DQG HYROXWLRQDU\ DQDO\VLV RI WKH LQIHFWLRXV HSLVRGHV VXPPDU\ WKH REYLRXV H[SODQDWLRQ ZRXOG EH WKDW WKH GHYHORSPHQW RI WKH YDULDWLRQV PLJKW KDYH RULJLQDWHG GXULQJ WKH FRXUVH RI LQIHFWLRQ 7KLV ZRXOG DJUHH ZLWK WKH ILQGLQJV RI 6WUDWLRQ DQG %DGHU > @ ZKR FBPSDUHG 615V\WZBRWGLQ\$ FBPSDUHG 4 'ÂQ W 0H... 1Vs4'Qp2?ÂHGh %DGHU > @ ZK

